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TEXTILES

BY

A. F. BARKER, M.Sc.

WITH CHAPTERS ON

THE MERCERIZED AND ARTIFICIAL FIBRES,
AND THE DYEING OF TEXTILE MATERIALS

BY W. M. GARDNER, M.SC., F.C.S.

SILK THROWING AND SPINNING

BY R. SNOW

THE COTTON INDUSTRY

BY W. H. COOK

THE LINEN INDUSTRY

BY F. BRADBURY

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PREFACE

In the following pages practically the whole range of Textiles comes under review, with the exception of certain very special branches, such as Trimmings, Hose-pipings, Beltings, etc. It is hardly to be expected that such a wide field can be satisfactorily covered by one writer, however well he may have been trained and whatever may have been his opportunities of gaining practical experience and insight. Thus, although I alone am responsible for the great bulk of the work, special chapters by recognised authorities have been introduced. Professor Gardner is responsible for the chapters on "The Mercerized and Artificial Fibres" and "Dyeing"; Mr. R. Snow for the chapter on "Silk Throwing and Spinning"; Mr. W. H. Cook for the chapter on "The Cotton Industry"; and Professor Bradbury for the chapter on "The Linen Industry." That these chapters add much to the practical value of the treatise will at once be conceded.

The authors hope that this work may prove of value to those who require extensive but accurate information on the whole range of the Textile Industries; that the

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technicalities dealt with in the work will serve well the practical man in his every-day difficulties ; and finally that the student desiring an all-round knowledge upon which to soundly base his later special knowledge will here find that which he seeks.

Aldred F. Barker.

The Technical College, Bradford,
February 16th, 1910.

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LIST OF ILLUSTRATIONS

List IV.—Importation of Colonial and Foreign Wool into the United Kingdom from 1800 to 1907.

	1800.	1810.	1820.	1830.	1840.	1850.	1860.	1870.	1880.	1885.	1886.	1887.	1888.	1889.	1890.	1891.
New South Wales	658	83	213	3,998	25,820	51,463	46,092	142,588	224,777	217,119	265,181	245,290	321,154	306,091	274,448	353,407
Queensland										104,361	84,065	106.614	122,867	126,637	144,093	173,558
Victorian	—	—	—	—	—	55,378	78,186	209,038	306,817	317,152	360,731	345,396	380,330	372,057	365,172	365,490
Tasmanian	—	—	180	4,005	11,721	17,468	16,731	17,039	23,653	21,681	21,463	22.261	20,167	22,035	23,537	25,855
South Australian	—	—	—	—	3,484	11,822	23,554	68,679	109,917	115,108	130,628	106,403	115,849	111,236	98,249	120,665
West Australian	—	—	—	—	—	1,046	1,992	5,260	9.211	14.427	16,862	17,656	19,382	22,897	27,949	26,933
New Zealand	—	—	—	—	—	1,502	17,870	106,660	189,441	237,875	260,912	272,918	265,681	277,726	292,724	315,055
Cape and Natal	—	15	29	—	3,477	19,879	55,711	124,050	190,614	182,168	227,289	234,728	288,910	287,334	283,494	316,510
Total Colonial	**658**	**98**	**422**	**8,003**	**44,502**	**158,558**	**240,136**	**673,314**	**1,054.430**	**1,209,891**	**1,367,131**	**1,351,266**	**1,534.343**	**1,526,013**	**1,509,666**	**1,697,473**
East India and Persian	—	—	—	—	7,611	9,704	62,226	44,090	112.716	93,699	118,525	123,945	134,170	140,868	125,670	133,767
China	—	—	—	—	—	—	119	337	1,672	3,426	2,393	2,149	3,789	5,455	8,200	15,316
German	1,170	2,221	14,609	74,496	63,278	30,491	19,681	16,459	28,119	9,700	12,005	9,589	5,356	7,358	4,592	3,335
Spanish	30,318	2,976	17,681	8,218	5,273	2,105	1,199	1,583	14,603	97	15,766	6,621	8,137	10,448	5,854	1,753
Portugal	9,622	16,772	475	2,319	1,569	7,361	24,503	9.287	14,356	7,634	8,589	9.764	10.020	11,110	7,684	7,188
Russian	25	868	150	1,680	11,776	9,758	22,150	18,474	45,417	63,368	65,027	66,422	59,802	106.263	65,506	96.205
Turkey, Egyptian & N. Africa	76	676	380	29	5,492	11,896	17,545	17,607	49,853	32,199	60,079	86,735	77,793	85.637	73,169	62,301
Peruvian & Chilian	—	601	25	64	40,004	39,731	69,068	64,173	52.876	65,691	49,927	69,942	56,235	67,047	57,500	62,068
Buenos Ayres & Montevideo	—	—	—	—	—	3,841	5,058	11,122	9,852	8,728	12,440	7,016	10,350	11.885	6,310	9,145
Falkland Is. & Punta Arenas	—	—	—	—	—	—	—	—	4,700	6,909	6,614	7,697	7,578	8.953	9,481	12,859
Italian & Trieste	84	683	334	14	4,055	1,536	719	832	2.565	928	1.574	1,636	1,187	2.758	1,058	2,494
Sundry	487	349	1.479	3.995	2,519	3,041	15.172	16,643	35.973	14,990	22,422	14,523	21.433	30.573	19.065	19,258
Goats' Wool	—	—	—	—	—	13,139	11,915	14,196	57,449	52,457	76,690	56,005	72,767	77,526	48,131	62,993
Total Bales	**42,440**	**25,244**	**35,555**	**98.818**	**186,079**	**291,161**	**492,491**	**888,117**	**1,484,581**	**1,569,717**	**1,819,182**	**1,813,310**	**2,002,960**	**2,091,894**	**1,941,886**	**2,186,155**

	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
New South Wales	373,757	310,534	347,277	369,037	293,759	316,754	282,574	276,303	248,408	353,091	278,181	233,922	209,023	240,922	223,648	308,628
Queensland	247,330	196,481	190,372	221,972	210,970	209,784	180,095	148,548	124,401	117,353	90,135	75,052	77,728	148,059	131,622	130,128
Victorian	385,914	347,036	382,937	418,560	345,445	358,717	301,772	292,166	255,131	375,843	299,643	224,787	226.133	261.724	221,684	330,326
Tasmanian	23,644	20,794	22,458	22,655	22,567	20,495	18,917	15,770	18,225	24,316	22,112	25,189	20,523	13,770	14.551	22,147
South Australian	112,166	104,838	103,462	115,717	118,616	90,055	60,326	61.444	50,720	86,556	66,157	67,001	60,019	76,469	78,579	89,637
West Australian	25,002	18,541	26.959	24,332	34,011	26,948	26,192	27,077	26,317	31,354	39,990	32,456	33,851	44,623	38,724	41,467
New Zealand	319,615	349.061	378,991	377,934	355,257	386,635	403,397	400,137	395,693	399,691	411,284	436,500	374,463	394,390	415,879	442,973
Cape and Natal	278,476	274,616	240,606	252,062	294,253	243,848	283,115	264,569	102,268	214,522	231,670	224,458	188,843	192.210	194,949	259,691
Total Colonial	**1,765,904**	**1,621,901**	**1,693,062**	**1,802,269**	**1,674,878**	**1,653,236**	**1,556,388**	**1,486,014**	**1,221,163**	**1,602,726**	**1,439,172**	**1,319,365**	**1,190,583**	**1,327,167**	**1,319,636**	**1,624,997**
East India and Persian	141,475	131,165	162,980	163,706	185,465	172,309	154,804	133,632	142.518	109,646	106,538	129,885	158,600	153,841	180,961	159,818
China	10,091	10,873	14,971	14,765	6,216	4,022	8,813	2,781	4,151	1,775	3,960	3,792	5,367	7,284	8,742	15,060
German	4,478	5,682	1,644	4,051	4,504	9,677	8.999	7,675	9,126	6,677	4,486	4,629	7,668	6,636	10,196	11,533
Spanish	3,079	4,742	1,631	10.638	4,240	12,948	3,110	3,481	896	1,293	2,128	1,413	2,392	1,732	2,139	4,077
Portugal	9,304	8.435	9,941	9,648	12,620	16,294	7,772	8,314	5,242	9,928	10,633	13,377	11,587	11,018	9,900	10,214
Russian	63.297	27,994	30,789	34,872	32,998	60,405	39,186	32,063	28,018	14,922	12,861	10,772	9,550	7,404	19,476	15,889
Turkey, Egyptian & N. Africa	81,901	55,614	40,094	67.056	42,435	53,984	32,935	28,363	39,108	26,746	36,692	39,802	53,712	43,104	53,856	51,725
Peruvian & Chilian	67,184	72,368	68,391	62,938	66,633	67,453	60,340	72,318	70,423	61,515	61,603	61,274	60.735	55.163	63,091	53,493
Buenos Ayres & Montevideo	15,368	16,734	23,980	38,659	31,026	47,931	41,205	20,109	22,077	53,150	37,220	45,026	22,719	52,839	59,254	70,343
Falkland Is. & Punta Arenas	13,615	15,087	16,413	18,017	19,504	23,498	27,645	30,019	28,784	35,395	39,403	39,027	41,589	34,903	41,884	53,249
Italian & Trieste	841	2,760	2,897	1,683	1,438	2.138	3.547	6,042	2,768	1,866	5,567	4,749	3,618	3,889	1,382	2,761
Sundry	23,935	20,322	24,777	45,139	34,629	50,034	48,729	62,508	37,150	45,463	58,165	42,467	48,706	46,485	47,943	43,176
Goats' Wool	71,170	67,061	66,873	94,412	50,473	95,487	89,511	107,290	69,445	77,514	104,644	109,868	100,939	101,712	100,350	109,077
Total Bales	**2,271,642**	**2,060,738**	**2,158,443**	**2,367,853**	**2,167,059**	**2,269,416**	**2,082,984**	**2,000,609**	**1,680,869**	**2,048,616**	**1,923,072**	**1,825,446**	**1,717,765**	**1,853,177**	**1,918,810**	**2,225.417**

Note.—Specially prepared by Messrs. Jacomb, Son & Co., of London.

Note.—The wool production of the United Kingdom increased 30 per cent. during this period.

TEXTILES

CHAPTER I

THE HISTORY OF THE TEXTILE INDUSTRIES; ALSO OF TEXTILE INVENTIONS AND INVENTORS

The authentic history of the textile industries has been carried so far back into the past ages by the archæological discoveries of the last hundred years that an interesting account of the evolution of these industries could readily be compiled. Such an account, however. while of interest from an archæological and historical point of view, might not be of much practical value: it would almost certainly be diffuse where concentration and triteness were desirable, and, possibly, too brief in dealing with those periods when change multiplied change causing a rapid and extensive evolution.

A sequential history of the development of the textile industries will here be preferable, although such will naturally sacrifice a certain amount of absolute accuracy to ensure a more perfect statement of the sequence of developments; perhaps even a sacrifice of actual historic order may at times be necessary to impress the real historic teaching involved. Not that in the following pages history is to be outraged and actualities suppressed or changed out of recognition; but rather that to gain all that history should teach us a certain practical licence will

be taken, its justification being in the clearness and precision thereby gained.

Throwing back our minds to the time when our ancestors were emerging from the barbaric state, we can well picture to ourselves their earliest dress as the skins of slaughtered animals. As the human race was probably evolved from the torrid-temperate zone (Central Asia), it is possible that some lighter form of wearing garment preceded the skins of animals for personal wear, But it seems very probable that the first idea of textures of real wearing value would be first thus suggested.

If any animal such as the sheep then existed, we can well imagine that the shearing of a fleece would suggest the matting together of fibres already favourably disposed for the formation of a continuous covering. Felt fabrics undoubtedly came early in the historic sequence; thus both garments and hats of felt were worn in Ancient Greece; while remains of felts can also be referred to a much earlier period. But wool being the only fibre which truly "felts," the felt industry naturally cannot go further back than to the discovery of the felting property of wool.

Wool could only be converted into a woven fabric by being spun into a "fibre-thread." Now prior to the spinning of "fibre-threads"—or yarns as we now term them—the art of interweaving rushes and other fibres or bundles of fibres of long length was undoubtedly practised, so that the art of weaving evidently preceded that of spinning in the natural evolution. Again, it is probable that the art of weaving preceded the art of felting, as it is a debateable point whether the art of felting preceded the art of spinning.

The spinning and weaving of fibre-threads or yarns are

obviously most delicate processes in comparison with rush and coarse fibre weaving; but it is nevertheless true that as far back as the early Egyptian Dynasties a most refined art of weaving was practised, so much so that to-day Egyptian mummy cloths of a gauze structure are found worthy of reproduction.

Turning to the conditions under which the arts of spinning and weaving would be practised in the early days of our civilization, we come across traditional industries retained in the family. It is more than probable that in some of the ancient civilizations the textile industries became more than family concerns, but so far as we are concerned we may regard the textile industry as essentially a family industry until the home industries—developed from family industries — appeared about the commencement of the eighteenth century. This does not discount the "Trade Guilds" which flourished in many centres of industry, such being based as much upon the family as upon a more highly organized form of the industry.

So long as all industries were distributed over the country it is evident that there would neither be the need nor the incentive for large production: the incentive would rather be towards the production of better fabrics and more artistic effects. Hence the marvellous beauty of many of the fabrics which came down to us from a very early date. And it is interesting and instructive to note that up to the nineteenth century attempts to introduce machines to facilitate production invariably claimed small consideration, while new methods of producing elaborate styles were certainly more than welcome. The "draw-loom" was

successfully introduced from China, but M. de Gennes' power-loom failed; Jacquard looms were in use long before the power-loom was either invented or adopted by the trade. Thus the art of producing elaborate and beautiful textiles followed civilization from the East to Southern Europe and from Southern Europe northwards. Marked indications of this line of development are still evident in the present-day organization of our industries, as will be shown later.

With the disturbance of the balance of production by the going forth of Europe's, but more especially England's, sons as colonizers would come the pressing demand for the greater production of certain commodities, of which cloth would be one. This would tend to break up the family traditions and to develop an industry organized on a larger scale, resulting in what might fairly be termed "specialized production" or organized home industries. Bringing groups of artisans together could not fail to stimulate industry and inventiveness, which in this case would naturally run on the lines of increased production. Now the Continent would naturally have shared in this evolution had it been tranquil and comparatively undisturbed as was England. But the Napoleonic wars were such a constant source of ferment on the Continent that tranquil, undisturbed England reaped nearly all the direct benefits of the very rapid evolution dating from this period.

About 1790 there commenced a natural evolution of the textile industries—spinning and weaving—the final result of which was to leave England for a long period of years practically supreme as a manufacturing country.

Prior to this evolution two kinds of spinning wheels were in use, one of which might be termed the "long-fibre

wheel" and the other the "short-fibre wheel." In the case of the long-fibre wheel (Fig. 9) a sliver of long fibres was practically made up from the raw material to the right thickness by hand and then twisted and wound on to the bobbin at the same time by the action of the flyer and bobbin. The attempt to use a double-spindle wheel no doubt suggested at an early date the more perfect and automatic production of slivers which might then be spun in greater numbers by hand. Thus in 1748 Lewis Paul developed the idea of drafting rollers. That he probably got the idea from seeing rollers used for elongating or working metal is indicated by the fact that it was thought possible that one pair of rollers would do all that was necessary, elongation of the sliver presumably being thought to vary with the pressure exerted. This mistake was soon rectified, and two or more pairs of rollers adopted. Richard Arkwright now came upon the scene and, linking up the drafting rollers of Lewis Paul with the long-fibre spinning wheel, made it possible to control more than one or two spindles at the same time. Arkwright then linked up the water wheel to this machine and thus evolved what is known as the "water-frame," yielding a type of yarn known even to-day by the term "water-twist."

It is probable that the "short-fibre wheel" was employed in the spinning of wool and of cotton—cotton was then a comparatively small industry[1]—both of which were woven

[1] Year 1701 :

Cotton Exports	£23,253
Woollen Exports	£2,000,000

Year 1833 :

Cotton Exports	£18,486,400
Woollen Exports	£6,539,731

into fabrics known as Lancashire woollens. Spindle-draft, as distinct from roller-draft in Arkwright's machine, was here employed, the reduction of a thick carded sliver into a comparatively thin thread being accomplished by mere extension, by the movement of the hand away from the spindle point, with the aid of a little twist; then upon the completion of the drafting the necessary twist was put into the thread. The process was intermittent, as winding on to the bobbin followed this drafting and twisting. The idea of working more than one spindle would here be more difficult of realization than in the case of the flyer, as the cycle of operations was much more complex. Improvements in the preparation of the slivers would here also forward the multiplication of the spinning spindles. Thus Hargreaves invented the "jenny," which was simply a multiplication of the spindles to be worked by hand, the action being really an exact copy of the mechanical operation of spinning on the "short-fibre wheel." This was soon followed by the "slubbing-billy," in which the position of spinning spindles and the slubbings were reversed, as in the mule of to-day. The "billy" was gradually developed by such men as Kelly, Kennedy, Eaton, and many others, into the hand-mule, and finally the hand-mule was successfully converted into the self-acting mule by Richard Roberts in 1830.

Much has been made of the invention of the "mule" by Crompton. But the truth is our ideas here need considerable revision. Crompton's idea of combining the drafting rollers of Arkwright's water-frame with the spindle-draft of Hargreaves' "jenny" was simply a "happy thought." Certainly this happy thought was combined

with a certain amount of resolution and skill in putting the idea into practice, but it should be noted that the woollen "mule" of to-day is not Crompton's mule at all, and in fact is not a "mule," but a "pure-bred," and all the really ingenious mechanism on both woollen, cotton, and worsted mules is not due to Crompton, but to the men mentioned above. It is further interesting to note that most of the complex mechanisms combined in the mule were known to spinners and would-be inventors prior to Roberts taking the mule in hand, but owing to their lack of power of sequential thought they all failed in devising a successful machine. It was Roberts who combined the ideas presented to him into a harmonious whole and gave to the world one of the most wonderful and ingenious machines which has ever been invented.

It will readily be imagined that the improvements in spinning just mentioned naturally resulted in a marked multiplication of yarn production. Curious to relate, however, there does not appear to have been over-production of yarn, but rather under-production of cloth. It is said of the hand-loom weavers of this period that they went about with £5 sewn in their hats, so remunerative was their art. The invention of Kay's "fly-shuttle" in 1738—an invention be it noted which could only affect production, not quality nor elaborateness of the resultant fabric—had been followed by others which brought the hand-loom up to the perfection of to-day. The word "witch"—applied to the shedding mechanism known to-day as the "dobby"—carries with it an indication of the way in which some of these innovations were regarded. The placing of two or more shuttles in movable planes or

shuttle-boxes, any of which could be brought into line with the picking plane, was possibly introduced in more places than one quite independently, while "permanent back-rests," "setting-up" and "letting-off" motions had developed, so far as might be, the possibilities of the hand-loom from the production point of view.

It is interesting to note that power was practically applied to the spinning frame earlier than to the loom. Arkwright's "water-frame" was successfully run shortly after 1769, while no practical power-loom was running until about 1813. By the middle of the nineteenth century hand-spinning was fast disappearing from all the manufacturing districts, but hand-weaving is even still continued in the twentieth century. Arkwright's "water-frame" was most easily rendered automatic; the spinning-jenny or "mule" up to a certain point was soon rendered automatic, but the completion of the necessarily complex cycle of operations automatically was not accomplished until Roberts faced the problem in 1825. The cycle of operations involved in weaving being more complicated than the "water-frame" cycle, but less complicated than the "mule" cycle, would naturally have come in between but for the difficulties in obtaining a steady drive; while the development of the comb into an automatic machine came much later than the "mule." Dr. Cartwright's first attempt at a power-loom was made without the slightest reference to a hand-loom and proved a failure. His second attempt was based perhaps too much upon the hand-loom, but may be regarded as having been fairly successful. It is well to fully realize that, while the introduction of water power facilitated spinning, it did not facilitate weaving to nearly

the same extent; simply because for weaving a really steady drive to ensure steady picking is necessary, and this was probably not by any means attained to in the early days of water-power driving. Later, when steam power was applied, marked improvements in steadiness were rapidly developed, with the result that practically most movements involved in ordinary spinning and weaving could be accomplished automatically from 1830 onwards. Then came the exodus from the country districts and the centralization of industries on or near to the coalfields. Thus it is interesting to note that prior to England becoming a manufacturing country the wool of England met the skill of Southern Europe in Flanders. Later a distributed industry is to be noted in England, the industry generally following the line of supply of the raw material. Still later the coal-power of Yorkshire meets the wool production of Yorkshire at Bradford, and the coal-power of England the cotton of America in Lancashire.

Attention was now turned to the more perfect preparation of the slivers of wool, cotton, flax, etc., for the subsequent spinning process. Hand-cards were early displaced by the roller hand-card, and this in turn developed into the "flat-card" and later the "revolving flat-card." The development of the card, however, was more of an engineering problem than a problem in mechanism, the style of build and accuracy of setting being the real difficulties. There is an exception to this, however, in the case of the woollen condenser. Originally cardings were left exceedingly thick and unwieldy, having to be drawn out into slubbings and then into slivers, finally to be spun on the wheel or jenny. The first improvement was the dividing

of the card-clothing on the last doffer into strips of 6 inches to 8 inches wide across the doffer, so that from the circumference of, say, a 24 inch doffer 10 or 12 slubbings just the width of the card—each say 27 inches to 36 inches long—would be stripped, these strippings being piecened up on the apron of the slubbing-billy by boys and girls called "pieceners." Then what was called a "piecening machine" was added, which, taking charge of these 27 inch to 36 inch slubbings stripped from the doffer, joined or placed them into continuous slivers, which were wound on to a spindle to be placed later on the slubbing-billy.

Some time after the introduction of the piecening machine the "condenser" made its appearance. In this the last doffer or doffers were clothed concentrically with rings of card-clothing, so that the slivers were stripped continuously from the doffer, and were practically endless as compared with the 36 inch slubbings stripped from across the doffer of the old card. In the latest form of condenser the wool is stripped from the last doffer in a continuous film, and then broken up into 70 to 80 filaments by means of narrow straps or steel bands. One wonders why the idea of the ring-condenser was not sooner thought of and why it should have been so frequently tried and discarded. A little thought, however, soon clears up this point. It may be taken that wool fibres take up a more or less concentric position on the card. If this be so, then stripping the wool off the old form of doffer would result in the fibres taking a concentric position in the thread, while in the case of the condenser they would take up a longitudinal position in the thread. This, no doubt, seriously affected the subsequent spinning, weaving, and

finishing properties; in fact, it is frequently stated that no fabrics equal to those made from yarn spun from the old piecening slubbings are to-day produced. Possibly the realization of this difference suggested the idea of preparing wool for combing by previously carding it. This was first carried into practice about 1847 and is to-day being largely applied even in the case of wools 8 inches to 10 inches long.

The cycle of movements in hand-combing being more complicated than the cycle of movements in carding, automatic combing naturally developed much later than automatic carding. The operations of lashing on, combing, drawing off, and the removal of "backings," of "milkings," and of "noil" were necessarily very complicated, and it was largely by the elimination of certain of these that mechanical combing was made a success. As with most other machines, the first mechanical attempts were simply imitations of the hand process. Dr. Cartwright from 1789 to 1792 brought out two forms of mechanical combs which after many vicissitudes were laid aside for many years until they both again emerged—the upright circle comb as Heilmann's comb, the horizontal circle comb in its most perfect mechanical form as Noble's comb. It should be noted, however, that it is Lord Masham (then Mr. S. C. Lister) to whom credit must be given for the creation of a practical wool comb: without his "driving-force" there can be no doubt but that the evolution of the wool comb would have been long delayed. As with spinning so with combing: the preparatory processes were of marked importance. Without the preparing or gill box and the card, mechanical combing would to-day be at least very imperfect if at all

possible. The "Genesis of the Wool Comb" is given in List I.

We have now dealt with the evolution of all the important textile mechanisms with the exception of the ring and cap frames, which may finally be briefly touched on.

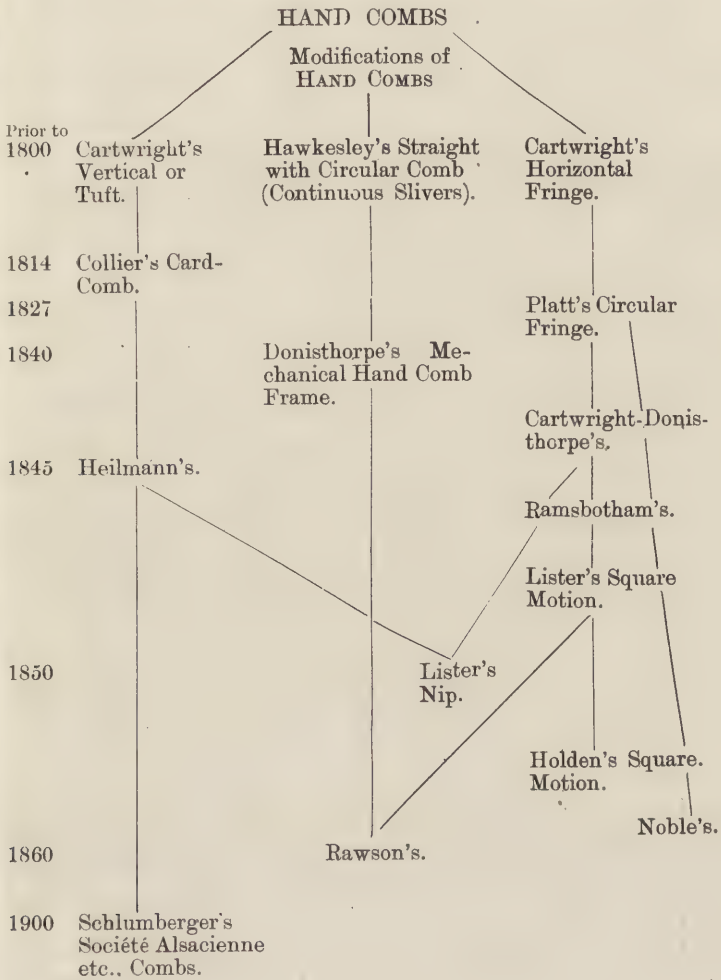
Labour, especially male labour, being very scarce in the United States, difficulties were encountered in working the heavy mules or mule-jennies needed for the production of certain yarns. Again, the questions of speed of machine and production would no doubt claim attention. Thus in 1832 the ring-frame was invented, this being readily controlled by female labour and eminently suited to the spinning of certain useful cotton counts.

Other ideas of frame spinning had naturally been tried in the States. The Danforth or cap spindle, coming to Lancashire about 1825, was condemned for cotton, but being introduced into Yorkshire was adopted as the system *par excellence* for the spinning of fine Botany yarns. It is curious to relate that the first trial of this spindle in Yorkshire was made at a very slow speed "to give it a chance." The result was that the yarn could be jerked off the bobbin or spool. It was only when the bobbin was speeded up from 2,000 to 5,000 revolutions per minute that its possibilities were fully appreciated.

From 1850 onwards—with the exception of the electric Jacquard and certain most interesting methods of pile weaving—no marked advances in the general form of the machinery employed in the textile industries are to be noted. Nevertheless, the improvements in details have been many and in some cases of surprising merit.

The development of pile weaving and of pile weaving

LIST I.—THE GENESIS OF THE MACHINE WOOL COMB.



machinery may briefly be summed up as follows: The printed warp pile fabric was introduced by Mr. R. Whytock about 1832. This was followed by the Chenille Axminster —in which the colours were woven in—about 1839. From 1844 to 1850 the power wiring loom was developed in the United States and introduced into Great Britain. From 1856 to 1867 the power "tufting" or Axminster loom was developed, and finally in 1878, Lord Masham succeeded in weaving two pile fabrics face to face, the pile stretching between an under and upper ground texture being severed in the loom by a knife which traverses from side to side with this object. From 1890 to 1910 the chief innovations have had reference to the cutting of weft-pile fabrics in the loom, the introduction of the looping or cutting wires through the reed, thus doing away with the necessity for any wiring mechanism, and certain marked improvements in the mechanism for producing Chenille Axminster fabrics.

Along with these developments came the factory system. This system was no doubt evolved by the disturbance of the balance of trade due to colonization and the various inventions noted. One thing reacted upon another, production increased production, spindle stimulated loom and loom spindle, until eventually a terrible strain was put upon those actually engaged in the factory, and in many cases humanity was sacrificed on the altar of increased production, most awful conditions prevailing. Slowly, however, the position of the worker has been improved both by direct and indirect legislation. Foreign competition has no doubt retarded still further improvements being carried into effect; but the *rapprochement* of nations due to increased facilities for communication must

Development of Mechanical Methods of Manufacture.

DISTAFF, HAND CARDS, HAND COMBS, JERSEY WHEEL, FLAX WHEEL, HAND LOOM.

1589	William Lee	Stocking Frame.
1650	M. de Gennes	Power Loom.
1738	John Kay	Fly Shuttle.
	Robert Kay	Drop Box.
1738	Lewis Paul, John Wyatt	Drawing by Rollers (ass power.)
1748	Lewis Paul	Roller Card.
1750	M. Vaucanson	Swivel Loom.
1758-59	J. Strutt	Rib Hosiery Frame.
1764	Jas. Hargreaves	Spinning Jenny.
1769	R. Arkwright	Water Frame.
1772	John Lees	Improved Card.
1779	S. Crompton	Mule.
1785	E. Cartwright	1st Power Loom.
1789	,,	Wool Comb.
1790	,,	Wool Comb, &c.
1792	,,	Wool Comb, &c.
1797	,,	Steam Engine.
1789	Jas. Watt	Steam Engine.
1790	Kelly	Power Mule.
	Johnson	Warp Dressing Frame.
1804	J. M. Jacquard	Jacquard Loom.
1813	Horrocks	Power Loom.
1823 to 1830	Heilmann, Jordain, Risler and Dixon, Sharp and Roberts	Power Looms Comb and Mule.
	Whitehead	Piecening Machine.

Development of Organization culminating in the Factory System.

1545 Principle of Interest admitted.
16th Century. Silk Mills at Bologna.
1609 Bank of Amsterdam.

Up to 1690. *Entirely Domestic.*

1610 Water power suggested for Spinning.
17th Century. Child Labour (6 years). German Spinning Schools (girls).

Up to 1730. *Combined Home, Warehouse and Mill.*

1718 Lombe's Silk Mill. (King's influence and power.)

Up to 1780. *Development of Domestic Industries. From Pack Horses to Waggons. Turnpike Roads. Riders for Orders.*

1738 Wyatt and Paul's Mill driven by two asses.
1750 to 1757 First Woollen Factory: in Workhouse.
1757 Water power fully employed.

After 1780. *Partners in London and on Continent. Agents, Factors and Brokers established. Market Days.*

1784 First Worsted Factory.
1786 Cartwright employs Steam Engine.

Development of Markets.

Prior to 1750.

Virginia.
West Indies.
Hudson Bay Territory.
Newfoundland.
Gibraltar.

Prior to 1800.

India.
Canada.
Florida.
Australia.
Ceylon.

Prior to 1850.

Cape Colony.
Natal.
New Zealand.
British Guiana.
Tasmania.
Mauritius.
Malta.

After 1850.

Opening up of China.
Japan.
Africa, &c.

inevitably lead to a levelling up and to labour ultimately receiving due recognition both with respect to the conditions under which work is done and the pecuniary benefits derived from such work.

In List II.,[1] the concomitant early developments of Mechanical Methods of Manufacture, Organization of the Industry and of Markets, are given.

[1] Note.—This list was given in a different form in the article on "Wool Combing" appearing in "Technics" for August, 1904.

CHAPTER II

THE WOOL, SILK, COTTON, FLAX, ETC., GROWING INDUSTRIES

THE sources of supply of raw materials must always claim the careful attention of spinners and manufacturers, even if they have not to deal with the material at first hand. It may be questionable if all the fluctuations in price of cotton, wool, etc., can be accurately gauged by the most careful study of the economic conditions of the supply; but of this we may be sure, that a sound knowledge of the conditions of production and consumption will in a large percentage of cases enable the spinner or manufacturer to correctly judge the situation and thus avoid mistakes which otherwise would most surely be made. We must not forget that the successful man is he who makes the fewest mistakes!

About a hundred years ago most wonderful advances were being made in both wool and cotton growing. The development of the Continental merino wool trade, followed by the still more remarkable development of the Colonial wool trade, and later by the development of the South American wool trade—these and other minor but important influences have resulted in changes of momentous issue. Cotton much earlier than wool seems to have felt the coming revolution, becoming acclimatized or being further developed in the United States of America, the East Indies, Peru, and later in Egypt. It is further interesting

to note that of late there has been a most decided unrest in cotton producing and consuming circles, resulting in the institution of the British Colonial Cotton Growing Association, which is at the present date (1910) threatening to again revolutionize the cotton markets. Silk also has made a remarkable advance, owing to the discovery of the possibilities of reeling certain wild silk cocoons and therefrom making a good quality of net silk. None the less remarkable have been the developments in the waste and artificial silk industries. Flax has never markedly changed its centre of gravity—at least so far as production is concerned—this no doubt being due to its being one of the fibres most easily spun by hand, and hence having been in general use prior to the industrial era. Its cultivation was much more distributed up to about 1870, but the chief centres of flax production, Ireland, Russia, Germany, Holland, and Belgium, are all old established. Other vegetable fibres, such as China grass, Phormium Tenax, etc., have from time to time appeared, and it does seem as if at last China grass has come to stay. The following sections, which must only be regarded as notes, give a broad outline of the development of the respective industries. Perhaps such notes possess a value which is not diminished but rather accentuated through their very brevity and triteness.

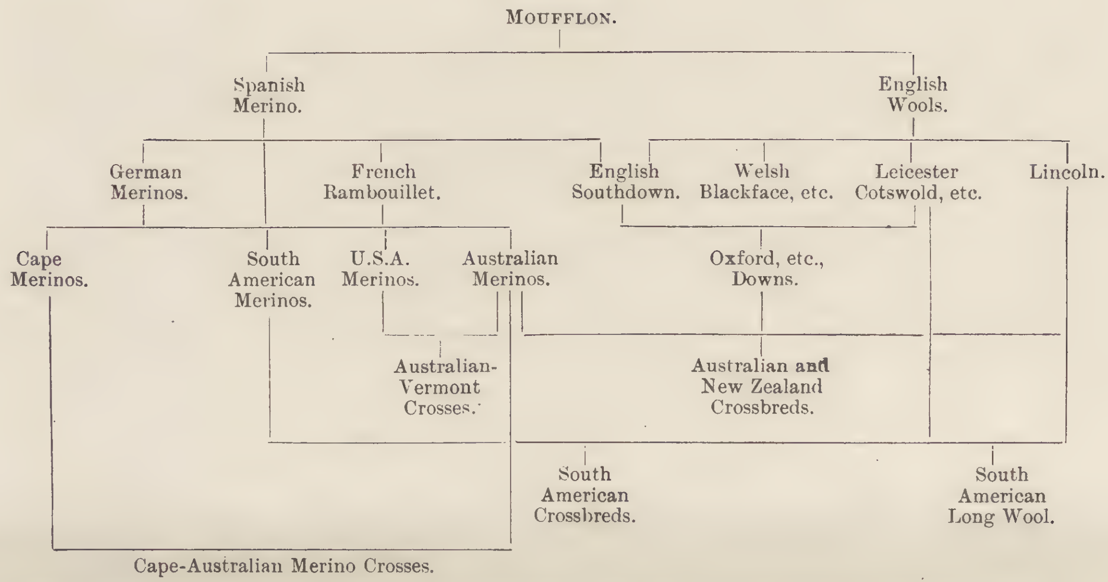
The Wool Growing Industry.—The sheep as we have it to-day is said to be a development, through years and years of selection and acclimatization, of a somewhat rough-haired animal, the moufflon, originally reared on the central plains of Asia. The evolution of the sheep was no doubt dependent upon the advancement in civilization of the peoples ultimately destined to spread not only over Asia, but

Europe and Northern Africa also. It seems quite probable that the Arabs following the north coast of Africa into Spain, took the partially developed sheep with them and by their well-known skill and carefulness, aided by climatic conditions, ultimately produced the Spanish merino, to which the merino flocks of the world owe their origin either directly or indirectly. At the same time that this evolution was taking place, the Asiatic tribes who struck northward across the central plains of Europe possibly also took with them the partially developed sheep which ultimately arrived in England, and again owing to climatic conditions became what we should now term a typical mountain sheep, from which within comparatively recent times the world-renowned English breeds of sheep have been developed by careful selection and breeding. An idea of this development is given diagrammatically in List III.

It seems more than probable that the moufflon or original progenitor of the sheep was black or brown, and it is interesting to note that there are continual reversions to this colour in some of our whitest and finest breeds—Wensleydales for example. So much has this tendency marked itself in certain parts of Australia that flocks of brown or black sheep have been established. The change in colour of the average sheep from brown to white is said to have been due to the custom of paying for shepherding with the white lambs dropped. This naturally led to the shepherds promoting the breeding of white sheep—as told with reference to Jacob in the Bible—with the final result that when the attempt was seriously made to breed pure white sheep success was soon achieved.

It is reasonable to suppose that the sheep as a supplier

LIST III.



Note.—Merino breeds are placed on the left, English breeds on the right, and Crossbreds in the centre.

So far as may be the history of each breed is shown vertically. Thus the French Rambouillet was probably the origin of the Vermont Merino, while the pure Spanish Merino was possibly transferred to the South American Colonies. Again, the Leicester breed is probably the most representative of cultivated English wools, etc.

of wool and mutton, was very widely distributed, and that the small quantities of wool produced would be spun and woven locally until some change upset this distributed equilibrium. So far as we can tell, the first change was due to the developed skill of the Continental workers, probably coming down the Rhine Valley and finally settling in Flanders. At least we know that the skill of the Flemish spinners and weavers was largely instrumental in creating England as a wool-growing country. The direct endeavours of several of the English monarchs coupled with Continental wars and persecutions ultimately resulted in the establishment of spinning and weaving industries in England along with wool growing. Nevertheless the centralization of industry was only partial until, as already pointed out, our colonization of new worlds, Continental wars, certain mechanical inventions, and the application of water and steam power gave rise to the factory system, which in its turn reacted upon the raw material producers and ultimately resulted in the development of the Cape, Australia, New Zealand, South America, the East Indies, etc., as the great wool-producing centres, although England still holds its own for its specially useful types of sheep. List IV. gives an idea of how these markets developed and at the same time affected the production of wool in the older wool-growing districts.

It will be noticed from these lists that the most marked development of the Botany wool trade took place between 1850 and 1880, coinciding with the development of combing machinery capable of dealing with fine short wools, and with the invention and development of the self-acting woollen mule. In fact these lists conclusively prove that

the development of the growing of fine wools was largely dependent upon the invention of machines with which to work them : thus the wool comb and the self-acting mule were really the deciding factors. Of course woollen yarn had previously been spun on the "billy" and "jenny," and Botany wool had been combed by hand, but these being all hand processes were the natural but very marked limitations, and it was only when these limitations were removed that the most noteworthy advance was made—just as the development of these improved hand methods had caused a marked rise in wool production fifty to seventy years previously.

It was the wonderful direct influence of the Australian climate upon the fleeces which first called attention to Australia as a possible fine wool-growing centre. The climatic conditions, however, were not the same all over the island continent, so that later developments have taken the line of heavier sheep of a greater value from a "mutton" point of view, with a consequent development in crossbred wool growing. When wool was down at a very low price in 1901-2, "mutton" became the chief factor in the case of all lands carrying crossbred or heavy sheep—as was also the case during these years in England. A large part of Australia, however, is only fitted for carrying the lighter merino breed, and thus will never be markedly affected by the frozen mutton trade. The drought of 1897–8, however, played havoc with these merino flocks, and a shortage of merino wool has resulted, which, in conjunction with the tendency to run off wool, owing to its poor paying results, and grow mutton, has finally resulted in a general shortage of wool and especially of fine wools.

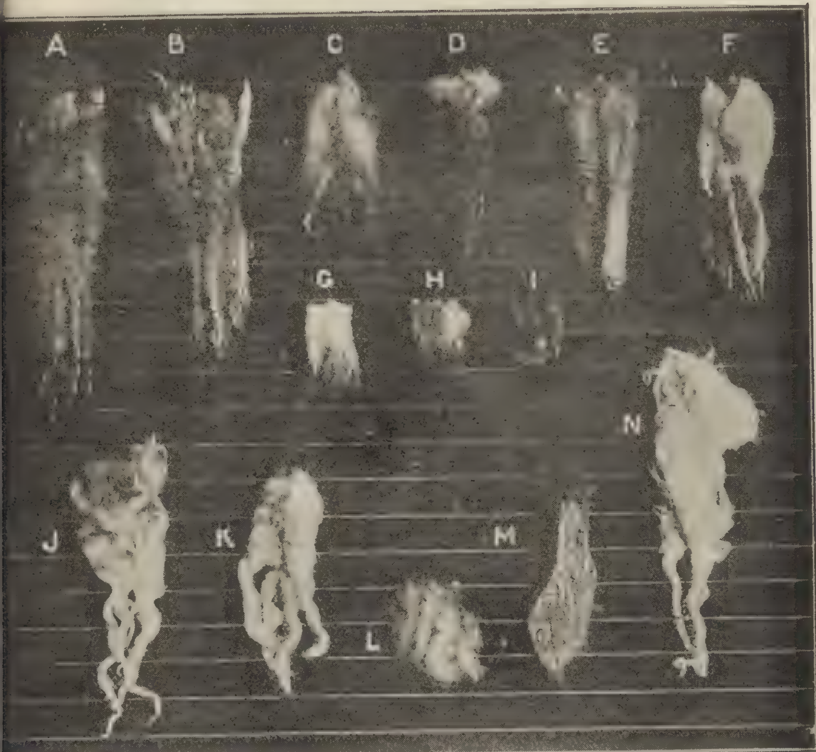


FIG. 1.—Wools and Hairs (the horizontal divisions = 1 inch). A, Lincoln; B, Kent; C, Shropshire; D, Australian Crossbred (46's); E, New Zealand Crossbred (46's); F, Buenos Ayres Crossbred (46's); G, Australian Merino (70's); H, Buenos Ayres Merino (60's); I, Cape Merino (64's); J, Turkey Mohair; K, Cape Mohair; L, Cashmere; M, Camel's Hair; N, White Alpaca. *Note.*—The presence or absence of grease on these natural wool staples has affected the colour.

New Zealand, having a climate more akin to that of England, has always produced wools of the crossbred type, merino sheep being bred in some few districts only.

The Cape has been a wool-producing country longer than

Australia, but climatically is apparently not so suited to the production of wool of good type. Of late much has been done to improve Cape wools, and they are naturally more sought after; but it seems as though it was a continual wrestling with nature.

Of recent years the country which has advanced most in wool production is South America. Originally a common sort of merino wool was grown, but now, owing to careful breeding and selection, both fine Botany and well-developed crossbred and even English wools are produced. The wool capabilities of the South American Continent are by no means exhausted, and it seems a pity that we English failed to realize the wonderful potentialities of a country likely in the near future to play such an important part in the world's history. It is principally to this country that the £1,000 Lincoln rams are continually being exported.

The United States of America very early attempted and succeeded in establishing flocks of sheep ranging from crossbreds to truly fine merinos, although, as already pointed out, they at first as colonists drew practically all their cloths from the mother country, and still take large quantities of the finer goods. That the United States is capable of producing a fine merino wool is proved from the use—rightly or wrongly—which has been made of the Vermont merino sheep in Australia. This use, however, has been made with the idea of producing a heavier fleece rather than a finer wool. America still buys English sheep and English wools, the importation of the sheep probably being necessary to correct the tendency to degenerate owing to climatic conditions.

Of the hairs manufactured into fabrics of various

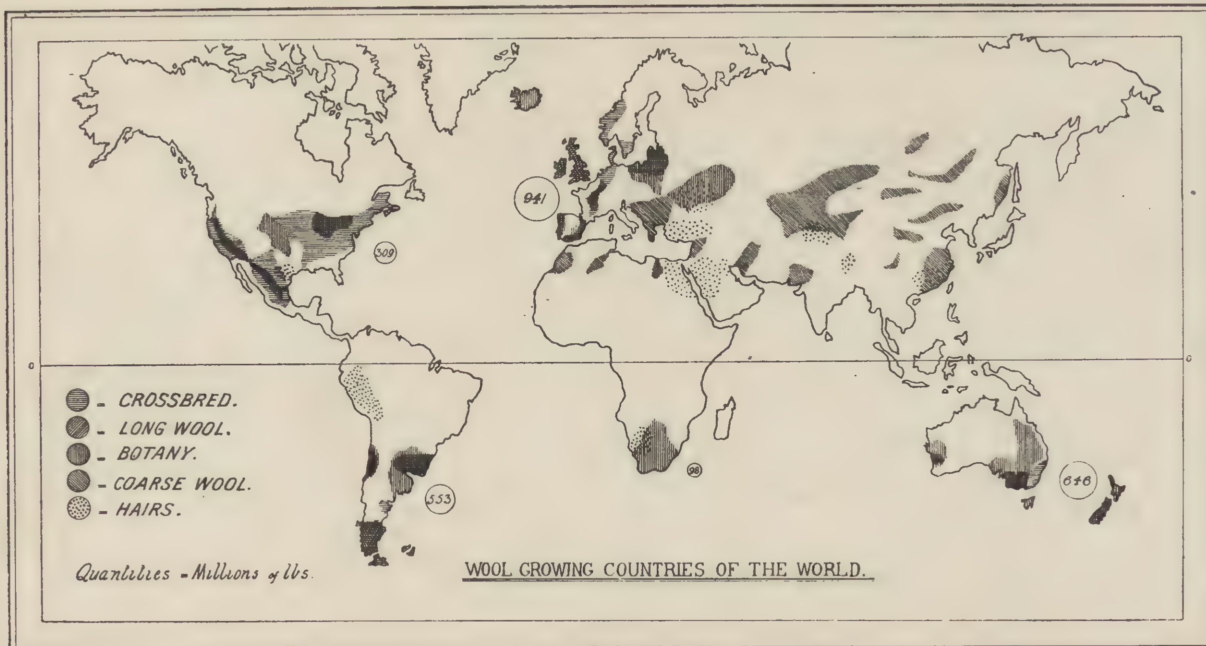

941
309
98
553
646
- CROSSBRED.
- LONG WOOL.
- BOTANY.
- COARSE WOOL.
- HAIRS.
Quantities - Millions of lbs.
WOOL GROWING COUNTRIES OF THE WORLD.

FIG. 2.

descriptions, Mohair, Alpaca, and Cashmere are the most important. Horsehair, Cow-hair, Rabbits' fur, etc., are used in small quantities only and for very special purposes.

That mohair was used in England two to three hundred years ago is evident from allusions to mohair fabrics made for example by Dryden. These fabrics, and later mohair yarns (hand spun), were no doubt imported from the emporium of the East, and it was only about 1848 that supplies in quantity of the raw material commenced to come into this country. Various restrictions were at first placed upon the export of the hair, but now it is an established trade and very considerable in bulk. More stringent restrictions were placed on the export of the Angora goat, but owing to a certain amount of vacillation flocks have been firmly established at the Cape and also bid fair to become established in San Francisco and Australia. Turkey mohair still maintains supremacy so far as quality of lustre is concerned, but Cape mohair, which, by the way, is clipped twice from the goat each year, now runs it very close. The Australian supplies are not yet of much moment, while the industries of the United States consume all grown in San Francisco.

Alpaca comes from the Peruvian sheep or goat. This hair, although used in various forms for centuries by the inhabitants of Peru, claimed no special attention in this country until Sir Titus Salt discovered it and produced his famous "alpacas." The fibre is long and silky and in some respects—notably softness—is superior to mohair. Most of the so-called "alpacas" sold to-day are actually made of mohair, for, curious to relate, while the supplies of mohair have quadrupled during the past fifty years, the supplies of

alpaca have almost remained stationary, as all attempts to naturalize the sheep outside Peru have failed.

Cashmere is obtained from the Cashmere goat, being the under-hair which is protected from the weather by a long coarse over-hair, and in turn no doubt serves the purpose of keeping the goat warm. This material came into notice as a useful fibre from the wonderful cashmere shawls which are so remarkable for their softness and fineness. The supplies of this material are in the hands of a select few and it is used for very special purposes. Soft, fine Botany wool is, however, frequently sold in a manufactured state as "cashmere."

Camels' hair is obtained chiefly from China and Russia. The coarser kinds or hairs are used for such purposes as camels' hair belting, while the "noil" or short soft fibre is used for blending with wools to yield special effects. The combing of this fibre, as also of Iceland wool, is very interesting, the idea frequently being to comb away the long fibres, leaving the "noil"—usually the least valuable part of the material—as a soft-handling and exceedingly useful fibre.

Cow-hair, rabbits' fur, etc., are only used for very special textures. Rabbits' fur, however, is used to a considerable extent in the felt trade.

Before leaving the wool industry reference must be made to the remanufactured materials, which briefly are Noils, Mungo, Shoddy, and Extract. The idea of using over again materials which have already served for clothing must be very old. It was not until 1813, however, that the Yorkshire clothiers succeeded in tearing up wool rags and therefrom producing a material capable of being spun into a fair yarn, especially if blended with other better materials.

The operations necessary for this "grinding-up," as it is technically termed (although in truth the operation more truly consists in a teasing out), are dusting, seaming, sorting (according to quality and colour), oiling, and grinding. Obviously hard-spinners' waste would be most difficult to reduce again to a fibre state, but machines are now made that will grind up at least anything of wool; cotton, however, is another matter. The terms mungo, shoddy, and extract refer to the original quality of the goods from which these materials are produced; mungo being produced from soft short wool goods, shoddy from longer and crisper wool goods, and extract from goods made of cotton and wool from which the cotton is removed by the "extracting" process, the remaining wool being then torn up into a fibrous mass.

To supply this trade large quantities of rags are imported into this country from the Continent, the Dewsbury and Batley districts working up a very large proportion. Quite recently the Americans made a very determined attempt to get hold of this trade, sending representatives into the Dewsbury district. They have undoubtedly been successful, although they cannot yet treat these materials quite so efficiently as the Dewsbury men. Germany has also a remanufactured materials trade of considerable moment.

The "noils" referred to above are the short fibres rejected from either English, Crossbred, or Botany wools, or Mohair, Alpaca, etc., during the combing operation. They cannot be considered as quite equal to the original material, although they are undoubtedly superior to mungo, shoddy, and extract: they may have lost a little of their elasticity, but their scale structure is not so much damaged, nor are they so much broken up.

All these materials are either used alone or, more frequently, blended with better or what one might term "carrying materials." Cotton and mungo, for example, often compose the blend for a cheap but effective yarn for the Leeds woollen trade.

The following tables, taken from Mr. F. Hooper's "Statistics of the Worsted and Woollen Trades," published by the Bradford Chamber of Commerce, give a bird's-eye view of the past and present constitution of the wool industry; similar particulars respecting the other industries are given in the special chapters devoted to them.

ESTIMATE OF WOOL GROWN IN THE UNITED KINGDOM IN 1907.

Chief Districts.	Sheep and Lambs.	Weight per Fleece.	Total Weight.
	(1906.)	lbs.	lbs.
Lincoln	993,983	9½	9,442,838
Yorks—East Riding	419,391	8	3,355,128
Devon	837,384	7	5,861,688
Ireland	3,714,832	6	22,288,992
Somerset	474,042	7	3,318,294
Shropshire	484,865	6	2,909,190
Sussex	399,001	4½	1,795,504
Wilts	468,743	4½	2,109,343
Scotland	6,994,338	5	34,971,690
Northumberland	1,067,697	6	6,406,182
Cumberland	586,432	6	3,518,592
Yorks—North Riding	683,877	6	4,103,262
Yorks—West Riding	678,876	6	4,073,256
Wales	3,586,095	3½	12,551,332
Sheep and Lambs in 1906	29,135,192	—	163,875,521
Slaughtered	11,113,187	at 3 lbs.	33,339,561
Net Clip of Wool in 1907			130,535,960

Exports of British Wool from the United Kingdom. In Thousands of Lbs.

Country.	1901.	1905.	1907.
To Russia	63	2,869	4,335*
,, Germany	1,067	2,531	3,417
,, Holland	829	962	916
,, France	606	760	936
,, United States	15,949	24,806	18,022
,, Canada	820	1,563	1,662
Totals for all Countries	20,206	35,252	31,087

* For 1906.

Imports of Wool into the United Kingdom. In Thousands of Lbs.

Country.	1903.	1905.	1907.
From France	15,781	21,338	24,487
,, Turkey	9,888	13,899	8,893
,, Chili	16,133	15,057	20,704
,, Uruguay	13,699	3,143	5,593
,, Argentine Republic	24,150	26,675	40,555
Totals from all Foreign Countries	107,049	111,764	137,133
From Cape of Good Hope	66,878	58,332	91,606
,, British East Indies	32,503	39,898	46,717
,, Australia	223,384	253,373	321,471
,, New Zealand	155,127	139,269	158,406
,, Falkland Islands	2,944	3,565	3,650
Totals from all British Possessions	492,452	503,944	622,104
Totals - -	599,501	615,708	759,237

RE-EXPORT OF COLONIAL AND FOREIGN WOOL FROM THE UNITED KINGDOM.
IN THOUSANDS OF LBS.

Country.	1901.	1905.	1907.
To Germany .	79,094	82,279	89,136
,, Holland .	21,950	12,580	9,144
,, Belgium .	43,219	39,251	57,852
,, France . .	96,531	60,424	83,711
,, Italy . .	664	32	908*
,, United States	47,379	78,756	69,889
,, Canada . .	2,257	1,824	917*
Totals for all Countries	293,063	277,103	312,673

* For 1906.

IMPORTS OF MOHAIR INTO THE UNITED KINGDOM.

Year.	From Turkey.		From South Africa.	
	lbs.	£	lbs.	£
1860	2,512,447	378,071	—	—
1865	5,056,037	786,915	9,609*	1,468*
1870	2,191,237	393,996	283,659	47,388
1875	5,461,832	753,907	1,079,293	89,700
1880	9,083,854	943,251	2,987,192	227,501
1885	6,828,502	607,365	5,263,813	305,196
1890	4,120,222	230,229	8,923,531	402,844
1895	11,875,640	787,964	10,354,870	492,531
1900	8,538,374	596,551	9,039,772	606,711
1905	12,524,356	807,901	12,532,482	779,967
1907	11,652,140	780,624	19,125,425	1,217,178
1908	7,460,507	477,344	17,810,975	935,702

* The first year that South Africa exported mohair in quantity.

Imports of Alpaca, Vicuna, and Llama Wool into the United Kingdom.

Year.	From Peru.		From Chili.	
	lbs.	£	lbs.	£
1860	2,334,048	263,635	520,402	58,443
1870	3,324,454	388,969	563,782	65,996
1880	1,412,365	98,644	890,627	64,621
1890	3,114,336	190,703	564,606	30,694
1900	4,236,566	205,839	1,148,694	51,116
1907	4,665,738	251,236	356,068	22,452
1908	4,309,912	257,215	515,754	26,968

Total European and American Wool Imports.

—	1901.	1903.	1905.	1907.
	Bales.	Bales.	Bales.	Bales.
Australasian . .	1,745,000	1,451,000	1,633,000	2,103,000
Cape . . .	217,000	234,000	209,000	287,000
Total Colonial .	1,962,000	1,685,000	1,842,000	2,390,000
River Plate . .	532,000	558,000	488,000	478,000
Total . .	2,494,000	2,243,000	2,330,000	2,868,000

The Silk Growing Industry.—At one time this industry was practically limited to China and Japan, in which countries the silkworm was rigorously guarded. Some missionaries, however, in the year 552 managed to bring some eggs to Constantinople, and eventually the industry was firmly established upon the north shores of the Mediterranean. Various attempts have been made to establish the industry elsewhere. Attempts, for instance, were made to acclimatize the worm in Ireland, and at the present moment a certain amount of success seems to be

attained in Australia; but rival industries or the unskilfulness of the rearers seem to prevent the attainment of any success of practical value. The United States, perhaps, may be regarded as exceptional in this respect. Not only have they developed their own breeds, but they have established a most complete silk industry from the worm to the finished product.

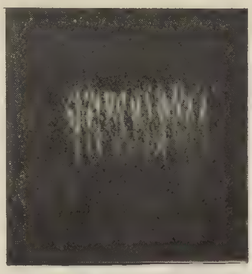
The most remarkable development in the silk industry was brought about in 1877 by Lord Masham, who, after many failures, succeeded in producing cheaply and successfully utilizing a most useful silk yarn from waste silks—old cocoons, brushings from the outside of the cocoons, throwing waste, etc. This development naturally lead to the utilization of wild silk, as tons of these pierced or spoilt cocoons —supposed to be unworkable—were available. Thus was developed the remarkable trade known as the "spun silk trade." Curious to relate, however, the latest discovery is that many of these wild silk cocoons can be reeled, as will be further explained in Chapter XV. The supplies of wild silks are not yet exhausted, as news is just to hand of the discovery of wonderful nests of cocoons in Africa (Congo State), arrangements for the exploitation of which are only just being made.

"Net" silk (silk threads reeled directly from the cocoon) comes to us in the form of what is known as "singles," a thread composed of just a few strands—say six. In the English "throwing mills" several of these singles are thrown together to make up a thread of the required thickness, with little twist if for weft, or, as it is termed, "tram," and much twist if for warp, or, as it is termed, "organzine" (see Fig. 21).

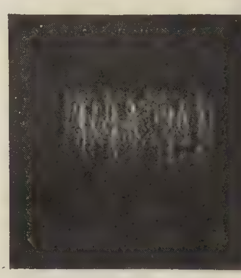
Waste silk is received in this country in three other forms, viz., wild cocoons, waste silk in the gum, and waste silk discharged. All these forms are, however, worked up on the same principle, which will be described later.

The Cotton Industry.—The cotton industry seems to be of Asiatic origin, and appears to have appertained more particularly to the Mahometan religion, as we hear of Mahomet going about with the Koran in one hand, a sword in the other, and a cotton shirt upon his back. As already pointed out, flax, being a material more readily spun, would naturally claim first attention. It seems probable, however, that India was unsuitable for flax cultivation, while the cotton plant was evidently indigenous. Thus attempts would no doubt be made to utilize this very nice-looking fibre, and eventually cloths very suitable for the Indian climate would be produced. These fabrics being shipped to Europe no doubt ultimately resulted in the cotton trade being established in various centres, but only on a very small scale. It was, as we have already seen, the mechanical era which gave life to the cotton trade and resulted in the development of the cotton-growing industry in the United States, the West Indies, Peru, the Sea Islands, Egypt, and later—under the auspices of the British Cotton Growing Association—in Africa. Our chief supplies of cotton still come from the United States. Egypt and the Sea Islands send us long-stapled cottons suitable for the Bradford trade, while Peru supplies us with a woolly cotton very suitable for blending with short wools for the Leeds and district trade.

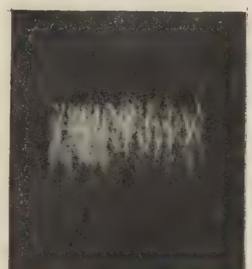
In Fig. 3 the chief varieties of cotton are illustrated.



WEST AFRICAN. Gambia. from American seed.

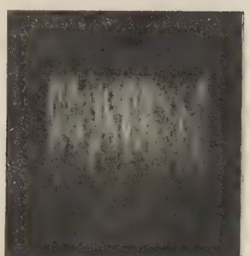


WEST AFRICAN. Lagos.

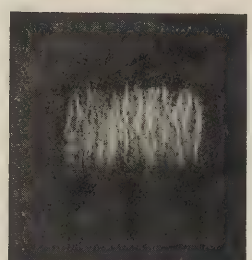


INDIAN. Oomrawattee.

INDIAN. Bengal.

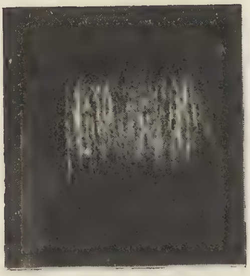


INDIAN. Broach.

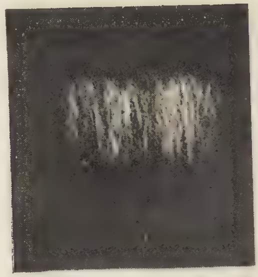


INDIAN. Tinnivelly.

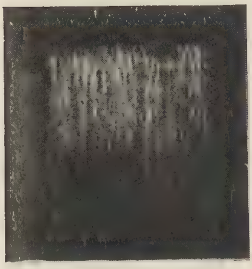
FIG. 3.—The Cotton Fibres of Commerce. Scale, $\frac{1}{2}$ inch to 1 inch. Arranged and photographed by F. W. Barwick, Esq., of the Research Laboratories, Imperial Institute.



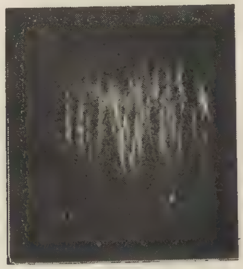
BRAZILIAN. Ceara.



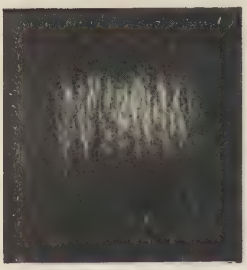
BRAZILIAN. Pernam.



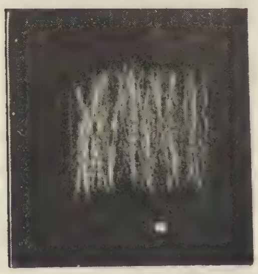
BARBADOS. Sea Island.



EGYPTIAN. Abassi.

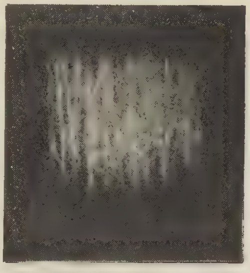


NYASSALAND. Egyptian.

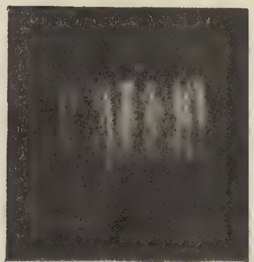


EGYPTIAN. Mitafifi.

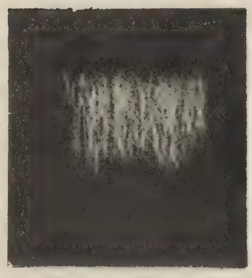
FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued*.



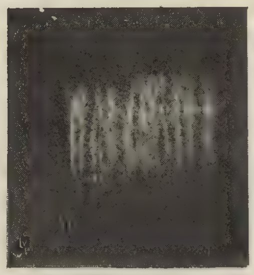
EGYPTIAN. Yannovitch.



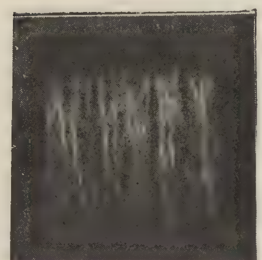
PERUVIAN. Smooth.



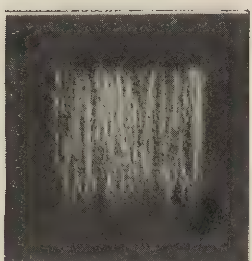
PERUVIAN. Rough.



PERUVIAN. Sea Island.

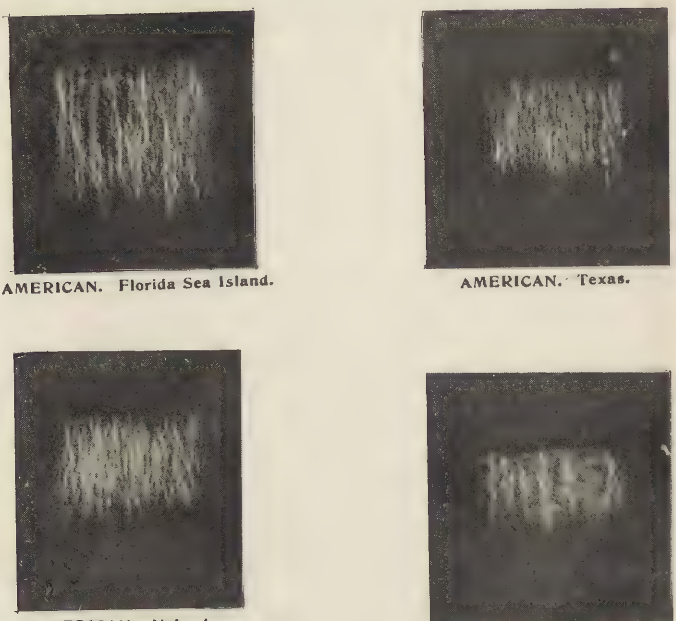


AMERICAN. Carolina Sea Island.



AMERICAN. Georgia Sea Island.

FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*



AMERICAN. Florida Sea Island. AMERICAN. Texas.

AMERICAN. Upland. CHINESE.

Fig. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*

The cotton-growing countries of the world are shown in Fig. 4, from which it will be noted that practically the torrid zone is the cotton zone. Of course soil and other conditions in part determine whether cotton can be grown, but it is evident that much heat is desirable and even necessary, and, as a consequence, that the best available labour is black labour. The United States has its "black belt," and in our attempts to grow cotton in our Colonies—and in the case of French Colonies also—it seems as though we must be largely dependent upon black labour.

The cotton fibre is produced on three varieties of plants;

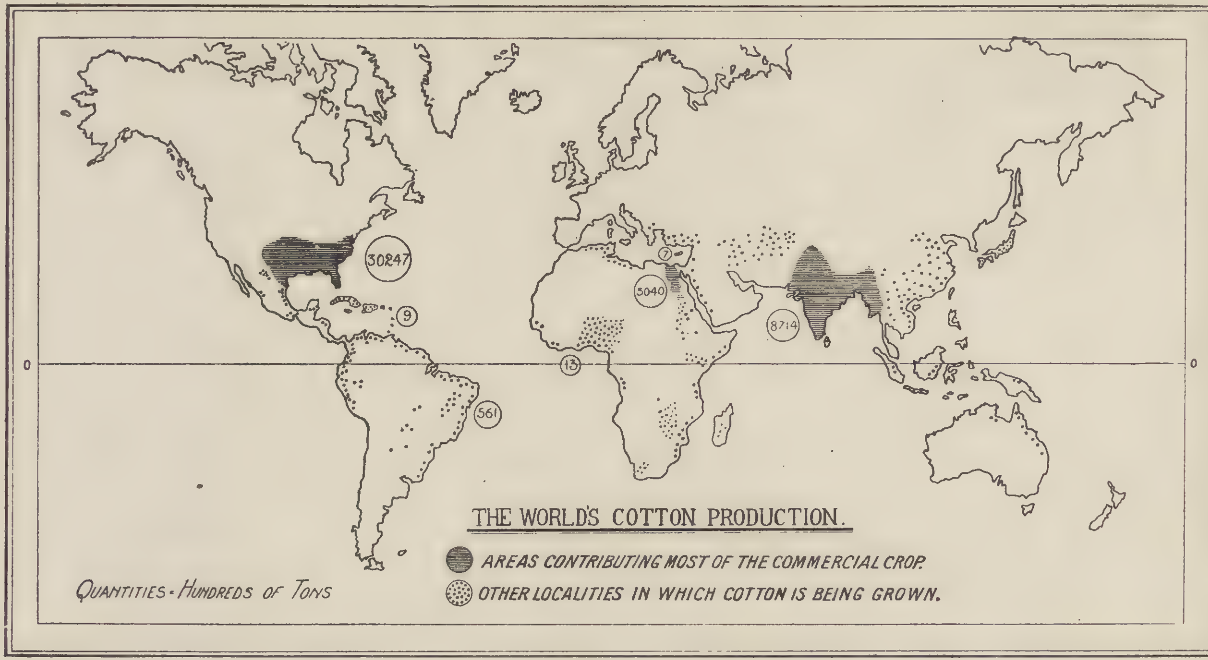

THE WORLD'S COTTON PRODUCTION.
AREAS CONTRIBUTING MOST OF THE COMMERCIAL CROP.
OTHER LOCALITIES IN WHICH COTTON IS BEING GROWN.
QUANTITIES - HUNDREDS OF TONS
30247
9
561
13
7
5040
8714
0
0

FIG. 4.

viz., Gossypium Barbadense, or the true Sea Island cotton plant, which, yielding the best type of cotton, is the original basis of much American, Egyptian, and Indian cottons; Arboreum or tree cotton, yielding a rougher cotton, coming to us from Brazil and Peru; and Herbaceum, or the variety of the ordinary cotton plant from which American cotton is largely produced.

The Flax Growing Industry.—The flax fibre is one of the oldest fibres of which we have any records. The Biblical references to flax (or linen) are numerous, and remnants of old linen fabrics are frequently coming to light in the exploration of the sites of the older civilizations. The writer has just been asked to analyse some linen fabrics dating back some 2,000 to 3,000 years. The following are the results:—

Analysis of Mummy Cloths.

	To-day's Cloth. Linen.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5
Weight per yard, 54 × 36	8 ozs.	$12\frac{1}{16}$ ozs.	$12\frac{7}{8}$ ozs.	$10\frac{5}{8}$ ozs.	$10\frac{3}{8}$ ozs.	$11\frac{5}{8}$ o
Counts of warp	1/33·5 linen	1/20·7	1/10·3 linen	1/32·7	1/21·8 linen	1/29· line
Counts of weft	1/31's linen	1/16's linen	1/10's linen	1/33·3 linen	1/18·4 linen	1/23· line
Threads per inch	46	60	28	84	50	80
Picks per inch	43	21	18	37	25	27
Strength of warp (single thread)	30·72 ozs.	..	2·77 ozs.		1·31 ozs.	1·65
Elasticity of warp (single thread)	·36″	—	·272″		·524″	·478
Strength of weft (single thread)	31·66 ozs.	—	5·01 ozs.	--	6·23 ozs.	1·7 o
Elasticity of weft (single thread)	·472″	—	·374″	—	·288″	3·34

The flax fibre, coming as it does from the stem of the flax plant, naturally requires very different climatic conditions as compared with the cotton fibre. Although its cultivation is still very dispersed, the chief flaxes are Irish, Belgian, Dutch, German, and Russian. The stems when ripe are cut somewhat after the fashion of corn, placed in the dam to rot or "ret," as it is termed, dried and "scutched," this latter operation resulting in the cortical or non-fibrous matter being separated from the fibrous matter. Dew retting is practised on the Continent, and sometimes chemical retting also; but whichever system is adopted, the idea is simply to separate the fibres from the cortical and pith-like substance with which they are enveloped with as little damage to strength, length, and colour as possible. Many substitutes for flax have come forward from time to time, but none have stood the test, with the possible exception of cotton, which seems to have made considerable encroachments during the past few years. China grass or Ramie may in the future have some influence on the flax industry, but it has hardly yet been felt.

Other Vegetable Fibres.—It is useful to obtain a general idea of all the vegetable fibres, as one cannot foretell which type is likely to come more markedly into use, or what particular type of plant is likely to yield a fibre suitable for special and up-to-date requirements.[1] In List V. the origins of the various "vegetable hairs" are given. In List VI. the physical compositions of the vegetable fibres are given.

[1] The use of Sisal hemp in the place of horsehair by the Italians is a case in point.

List VII. is a practically complete list of the vegetable hairs and fibres.

List V.—Vegetable Hairs.

Origin.	Natural Order.	Typical Example.
Entirely covering, or in part covering the seed	Malvaceæ	Cotton.
	Asclepiadaceæ	Madar Fibre of India.
	Apocynaceæ	Periwinkle.
	Œnotheraceæ	Willow-Herb.
Contained in the flower .	Typhaceæ	Bullrush.
	Cyperaceæ	Cotton Grass.
Lining interior of fruit .	Bombaceæ	Horse-chestnut.
		Red Silk Cotton of India.
Twigs and leaves . .	Filices	Ferns.
	Muscineæ	Peat-moss Fibre.

List VI.—Vegetable Fibres.

(*a*) Fibres formed of Single Cells:

Ramie—disintegrated.
China Grass—disintegrated.
Flax—disintegrated (*i.e.*, too far retted).

(*b*) Fibres associated in Bundles:

Jute—unbleached.
Flax.
Deccan Hemp.
Ramie—not disintegrated.
Hemp—well prepared.

(*c*) Fibres together with Medullary Ray Cells:

Sisal Hemp.

(*d*) Fibres together with Parenchyma Cells:

Sunn Hemp.
Mudar Fibre of India.

(*e*) Fibres and Vessels:

Phormium tenax or New Zealand Flax.
Musa or Manila Hemp.
Ananas or Pineapple and Banana Fibre.

List VII.—Complete List of Vegetable Hairs and Fibres.

Technical Name.	Local or General Name and Location.	Scientific Name.
Cotton. .	1. Tree Cotton . . .	Gossypium arboreum.
	2. American, African, and Indian Cotton	,, Barbadense.
	2a. Sea Island Cotton . .	,, maritimum, etc.
	2b. Peruvian or Brazil Cotton	,, acuminata.
	3. Asiatic Cotton . .	,, herbaceum.
Kapok .	White Silk Cotton of East Indies	Eriodendron Anfractu.
Semal . .	Red Silk Cotton of India .	Bombax Malabaricum.
Silky Cotton	Down Tree of Armenia and Jamaica	Ochroma Lagopus.
,, ,,	White Silk Cotton Tree of India	Cochlospermum Gossypium.
Vegetable Silks	"Mudar" or "Yercum" of India	Calatropis gigantea. ,, procera.
,, ,,	Of Bengal	Beaumontea grandiflora.
,, ,,	"Yachan" of the Argentine	Chorisia insignis.
Flax . .	Flax or "Lin" . . .	Linum usitatissum.
Hemp . .	Sunn Hemp . . .	Crolalaria juncea.
,, . .	Sisal of India and Queensland	Sida rhombifolia.
,, . .	Manila Hemp . . .	Musa textilis.
,, . .	Sisal Heneopien or Yucatan Hemp. (An aloe)	Agave rigida. Var. longifolia.
,, . .	Chinese Hemp . . .	Abutilon, etc.
,, . .	Common Hemp . . .	Cannabis sativa.
,, . .	Rajmahel Hemp of Northern India	Marsdenia tenacissima.
White Rope Fibre	Bombay or Manila Aloe of America and East India	Agave vivipara.
,, ,,	Istle of Mexico . . .	,, heteracantha.
,, ,,	Maritius Hemp of South America	Fureroea gigantea.
Flax-like Fibres	Buaze Fibre of Guinea and Nileland, etc.	Securidnea longipedum culata.
,, ,,	Siberian Perennial Flax .	Linum perenne.
Flax and Hemp Substitutes	Spanish Broom . . .	Spartum junceum.
	Kendu Fibre . . .	Apocynum Venetum.
Jute . .	Jute of India and China .	Corchorus capsularis.

List VII.—Complete List of Vegetable Hairs and Fibres—*continued*.

Technical Name.	Local or General Name and Location.	Scientific Name.
Jute . . .	Jute of Calcutta . . .	Corchorus Olitorius.
,, . .	,, America . . .	Abutilon Avicennæ.
,, . .	,, West Africa . .	Honckenya ficifolia.
Jute-like Fibres	Fibre from Lagos . .	Honckenya ficifolia.
China Grass	Tchon Ma (Temperate Zone)	Boehmeria nivea.
,, ,,	Ramie or Rhea (Torrid Zone)	Variatum tenacissima.
,, ,,	Canada Nettle Fibre . .	Laportea Canadensis.
Nettle Fibres	Tashiari (Himalayas) . .	Debregeasin Hypolenca.
,, ,,	Nilgiri Nettle . . .	Girondina heterophylla.
,, ,,		Maontia purga.
,, ,,	Ban-Surat of India and Ceylon	Laportea crenulata.
,, ,,	Ban-Rhea of Assam . .	Villebrūnea intergrifolia.
,, ,,	Urera Fibre of Natal . .	Urera tenax.
,, ,,	Mamaki of Pacific Islands .	Pipturus albidus.
,, ,,	Rere of Pacific Islands .	Cypholobus macrocephalus.
Palm Leaf Fibres	Oil Palm Fibre . . .	Eloesis Guineensis.
,, ,,	Gri-gri Fibre of West Indies	Astrocary.
,, ,,	Raffia of Madagascar and Africa	Raphia Ruffia.
,, ,,	Corogo Fibre of Cuba .	Acrocomia Lasiospatha.
Special Fibres	Plantain and Banana Fibre	Musa sapientium var. paradisiaca.
,, ,,	Pineapple Fibre of East India	Ananas sativa.
,, ,,	Caraguata of Paraguay .	Bromelia Argentina.
,, ,,	Pingum of Jamaica and America	,, ,,
,, ,,	Silk Grass of Jamaica and Tobago	Bromelias or Furcroea Cubensis
,, ,,	Madaguxar Piassava . .	Diety osperwa Piassava.
Hibiscus or Mallows	Deccan Hemp. Also known as Kanaff and Ambari Hemp	Hibiscus Cannabinus.
,, ,,	Okro	,, esculentus.
,, ,,	Royelle or Red Sorelle .	,, Sabdariffa.
,, ,,	Maholtine (Africa and America)	Abutilon periplocifolium.

List VII.—Complete List of Vegetable Hairs and Fibres—*continued.*

Technical Name.	Local or General Name and Location.	Scientific Name.
Hibiscus or Mallows	Ban-ochra of India, or "Toza" Fibre of West Africa	Urena lobata.
,, ,,	Indian Mallow Hemp . .	Abutilon Avicennæ.
Leguminous Order	Dhunchi Hemp of Assam .	Sesbama aculeata.
,, ,,	Ka Hemp of China and Japan	Pueraria Thunbergiana.
,, ,,	Maln Fibre of India and Ceylon	Banhima Vahlii.
Bowstring Hemps	Konje Hemp of Zambezi, etc.	Sanseviera Guinensis.
,, ,,	,, ,, ,,	,, longiflora.
,, ,,	Pangane Hemp of Pangane	,, Kukii.
,, ,,	Neyanda of Ceylon . .	,, Zeylanica.
,, ,,	Ife Hemp of South Africa .	,, cylindrica.
,, ,,	Moorva of India . . .	,, Roxburghiana.
,, ,,	Somali Land Fibre . .	,, Ehrenbergii.

The average lengths, practical and actual, and the average diameters of the principal vegetable fibres are given in List VIII. In Fig. 5 the countries producing the more important vegetable fibres not specially dealt with here are indicated. The only fibres in these lists which call for special comment are hemp, jute, and the two forms of China grass.

Jute is the fibre from what is essentially a torrid zone plant and is largely used in the carpet industry for sackings, while hemp is not quite so much of a torrid zone plant and is more particularly used for ropes, especially for shipping, as it sinks in the water, while ropes of some other materials

do not sink so readily and are thus dangerous to small boats passing by.

List VIII.—Working Lengths and Average Diameters of the Principal Vegetable Fibres (in inches).

Name.	Working Length.	Average Diameters.
	inches.	inches.
1. Agave Americana or Sisal Hemp. *Agave rigida var. Sisalana* (True Sisal hemp)	36—60	$\frac{1}{250}$ — $\frac{1}{62}$ average $\frac{1}{130}$
2. Ananassa or Banana Fibre. *Ananas Sativa* (Pineapple Fibre)	18—72	$\frac{1}{830}$ — $\frac{1}{230}$,, $\frac{1}{410}$
3. Boehmeria Nivea or China Grass	up to 11	$\frac{1}{1250}$ — $\frac{1}{330}$,, $\frac{1}{660}$
4. Boehmeria tenacissima or Ramie	ditto	ditto
5. (*a*) Common Hemp . .	48—84	
(*b*) Piedmontese or Giant Hemp	up to 144	$\frac{1}{1660}$ — $\frac{1}{500}$,, $\frac{1}{1330}$
6. Corchorus olitorius or Jute.	60—120	$\frac{1}{1660}$ — $\frac{1}{500}$,, $\frac{1}{1430}$
7. Crotalaria juncea or Sunn Hemp	72—144	$\frac{1}{2000}$ — $\frac{1}{880}$,, $\frac{1}{1250}$
8. Linum usitatissimum or Flax	24—36	$\frac{1}{1660}$ — $\frac{1}{660}$,, $\frac{1}{1000}$
9. Musa textilis or Manila Hemp	up to 60	$\frac{1}{500}$ — $\frac{1}{83}$
10. Phormium tenax or New Zealand Flax	36—132	$\frac{1}{312}$ — $\frac{1}{66}$,, $\frac{1}{104}$

China grass (*Boehmeria nivea*) has so often been to the fore as a newly discovered fibre and so often proved a failure that one hesitates to speak of it. The Chinese, however, make such magnificent textures from this fibre that its prospects cannot be regarded as other than hopeful. Whether the Indian form of the fibre, ramie (*Boehmeria tenacissima*) as it is frequently called, will ever yield such a plastic wonderful yarn and fabric as the Chinese get from

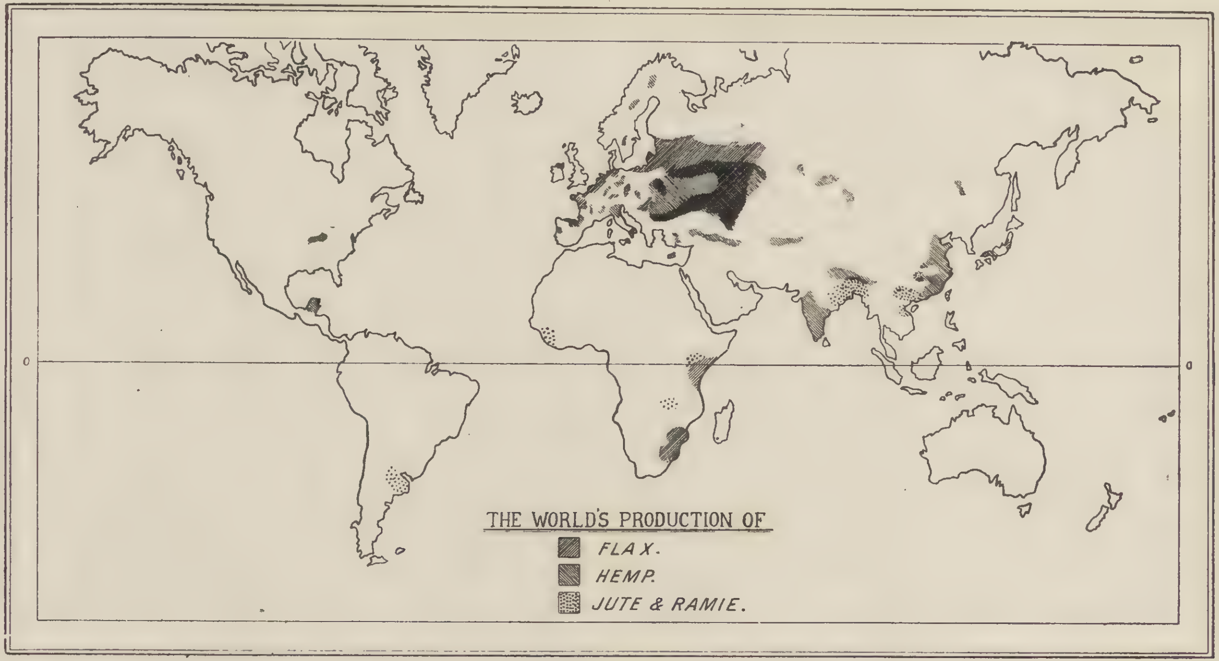


FIG. 5.

China grass (*Boehmeria nivea*) still remains to be seen. Certainly the possible need for indigo planters turning their attention to growths other than indigo should at least favour a really serious trial. The gums in China grass are the greatest difficulty, necessitating its being prepared in a way entirely different from linen; when it is satisfactorily prepared it is so silky that waste silk machinery is the most suitable for dealing with it.

At the present moment a great revival in the New Zealand flax (*Phormium tenax*) industry is taking place. Whether success will attend the endeavours being made remains to be seen, but of this we may be certain, that there are still many fibres only partially exploited, and many which have not even been touched, which in the future are undoubtedly destined to play a useful part.

Notes on the Chemical and Physical Structures of the Fibres. —The textile fibres of commerce naturally group themselves into six well-defined groups, viz., the animal fibres, the vegetable fibres, the animal-vegetable or insect fibres, the mineral fibres, the remanufactured fibres, and the artificial fibres.

Of the first class the normal wool fibre may be taken as representative. It is composed of carbon, oxygen, nitrogen, hydrogen, and sulphur,[1] and when burnt emits a disagreeable odour largely due to the liberation of ammonia, which serves to distinguish it from cotton and most other fibres. It does not burn with a flash, as does cotton, but rather shrivels away, leaving a bead of burnt matter. Wool has marked powers of causing dissociation of certain metallic salts, this forming the basis of the mordanting of

[1] In what manner these elements are combined chemists are still uncertain.

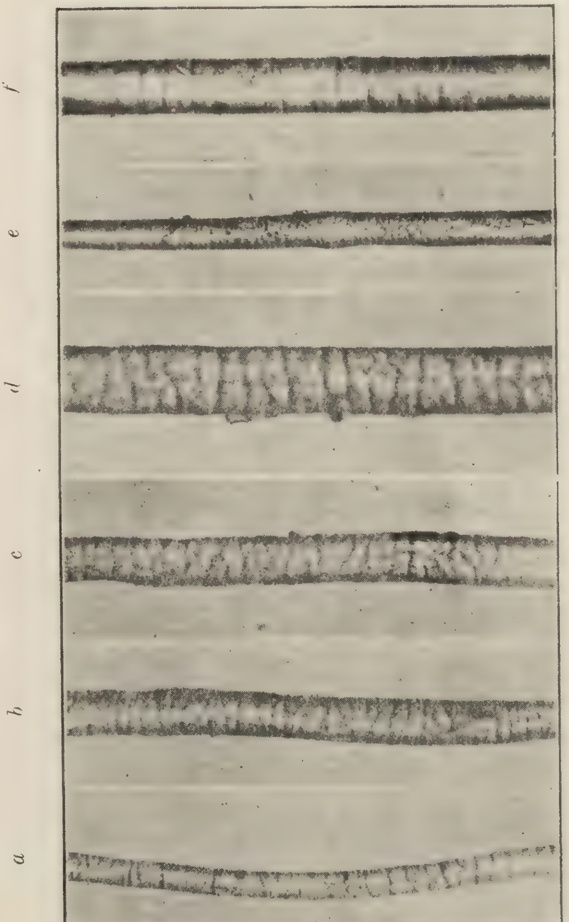


Fig. 6.—Micrographs of Wool Fibres: (a) Merino (Australian), (b) Southdown (English), (c) Cross-bred (New Zealand), (d) Lincoln (English), (e) Alpaca (South American), (f) Mohair (Turkish).

wools prior to dyeing. It is open to doubt as to whether the action of dyeing is entirely a chemical or partly a physical action. In the case of indigo dyeing, for example, there seem marked indications that the action is purely physical.

On the other hand, this cannot be said with the same certainty of most other dyes. Physically, the most remarkable thing about wool is its exterior scale structure (clearly shown in Fig. 6), to which it partially owes its felting property, and to which in part wool cloths owe their strength. Various qualities of wools have this exterior scale structure developed in different degrees, and as a rule those with the scales most marked "felt" the most easily, although there are exceptions to this rule, curliness and probably internal structure playing some part. Hairs only show more or less faint indications of the scale structure, and consequently do not felt so readily. Upon the other hand, they are usually more lustrous, their uncorrugated and unbroken surface reflecting the light intact. In fineness wool fibres vary from $\frac{1}{500}$ to $\frac{1}{3000}$ of an inch in diameter, but there is no well-defined relationship between fineness and length, although the Bradford quality numbers—now practically universal—such as 30's, 40's, 50's, 60's, 70's, etc., no doubt suppose some general coincidence between length and fineness of fibre. A year's growth in length may equal anything from 1 or 2 inches to 12 or 16 inches, a fair average being 7 to 8 inches. Wool, however, if left unclipped, will grow sometimes to 40 inches in length, and fleeces are on record weighing 57 lbs. The length of the wool fibre, as will be demonstrated later, largely determines the method of preparing and spinning it into yarn.

Of the second class, cotton is the most representative of the "seed-hairs." It is nearly pure cellulose, the formula for which is $C_6 H_{10} O_5$. Flax and the other "stem-fibres," while largely composed of cellulose, are much less pure

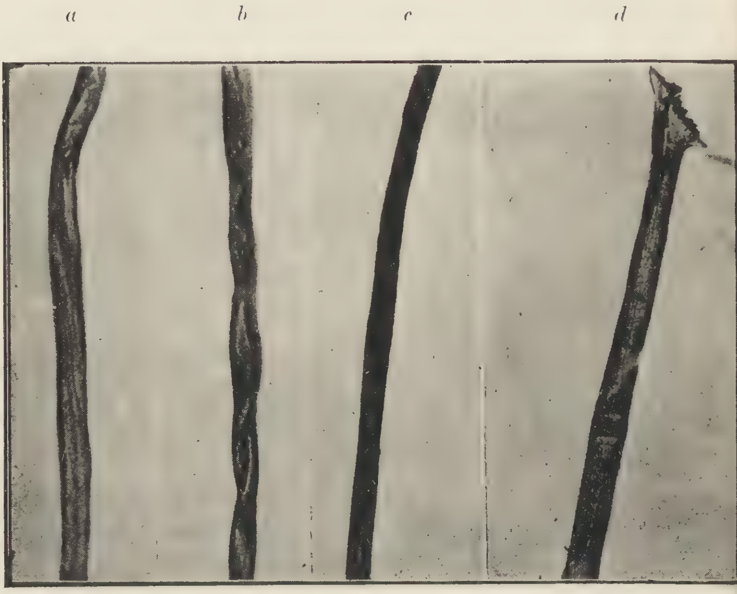
in composition, and in many cases by their very impurities may be distinguished from one another (see List VI.).

Physically, cotton appears to take the form of a flattened, collapsed, twisted tube; in fact its form is best suggested by a thin indiarubber tube out of which the air has been drawn. If unripe, the characteristic feature of twist is absent, and the cotton neither dyes well nor does it spin to advantage. In length the cotton fibre varies from $\frac{7}{8}$ of an inch to $1\frac{3}{4}$ inches and in diameter averages about $\frac{1}{1344}$ of an inch. Fig. 7 illustrates some interesting features respecting the structure of the cotton fibre.

The chief characteristic of flax as viewed under the microscope is the appearance of nodes, these, no doubt, being limitations of growths. Flax may readily be recognized by the property it possesses of developing curious cross striations when treated with nitric acid and then sulphuric acid and iodine. Most of the vegetable fibres may be recognized by some special chemical reaction. Thus jute, for example, may be distinguished from flax, etc., by the action of an acidulated alcoholic solution of phloroglucine, flax being unchanged, while jute is stained an intense red.

Of the third class silk is the representative fibre. In most of its chemical reactions silk is akin to wool, but there are differences which enable the dyer to cross-dye silk and wool goods—*i.e.*, to dye the silk one colour and the wool another colour, although there are obvious limitations in this respect. The silk fibre consists of two distinct parts, a central portion and a coating of substances readily removable by hot water, termed the "silk gum." The central portion or "fibroin" has approximately

the composition: $C_{15} H_{23} N_5 O_6$. The silk gum, which often forms as much as 20 to 30 per cent. of the natural silk fibre, is usually boiled off, and only too often weighting added, which has a deleterious action on the wearing



FIGS. 7 and 8.—Micrographs of Cotton Fibres: (*a*) unripe fibre, (*b*) ripe fibre, (*c*) mercerized fibre. Micrograph of Silk Fibre: (*d*) illustrates the twofold character of the silk fibre and the splitting and expansion of the fibrils which occur in some Tussah Silks.

qualities of the silk. Why silk should so readily weight-up does not entirely admit of a satisfactory explanation. It is, of course, a most expensive fibre, and as weighting agents cost 1*s*. per lb. and as silk sell at 12*s*., weighting naturally pays well. Physically, silk may be defined as a

long fibre (cocoons contain from 400 to 1,500 yards) of a twofold character, this being due to the silk fluid issuing from a gland on each side of the silkworm, the ducts from these uniting in the head of the worm. Under the microscope the fibre appears more as a glassy rod of fairly round form (Fig. 8), but from time to time the twofold character is perceptible in following along the fibre. In fineness it is from $\frac{1}{500}$ to $\frac{1}{1600}$ of an inch, the finer being the cultivated silks and the coarser the wild silks. A peculiar feature of the wild tussah silks is that upon the fibre being cut it breaks up into a number of fibrils, forming a bush-like end. This makes the fibre specially suitable for the production of plushes.

The mineral fibres are principally glass, tinsel, and asbestos. As they are of very limited application, their chemical composition and physical qualities need not be fully discussed here. Glass naturally partakes of the qualities of ordinary glass, but is much more flexible than would be naturally supposed. Tinsel is made from copper, aluminium, and other metals drawn out, and partakes naturally of the qualities of the metals from which it is made. Asbestos possesses characteristics which cannot be well defined on paper. As woven into cloth it is irregular, lumpy, soft, and plastic. It is naturally mostly employed next to heated surfaces, for firemen's jackets, etc.

The remanufactured fibres can only claim distinctive treatment from the physical point of view. They mostly consist of animal fibres which have been broken up in length and the scale structure of which has been partially damaged. The important quality of elasticity has also been seriously interfered with.

The artificial fibres are of such importance that it has been deemed advisable to devote a special chapter to them.

Notes on the Effects of Chemical Re-agents on the Textile Fibres.—The effects of even simple re-agents are so marked and so diverse that it is very necessary to have an accurate and extensive knowledge of such under all the varying conditions obtaining in practice. For instance, boiling water will disintegrate and weaken wool while it strengthens cotton. Again, sulphuric acid and caustic soda have very different actions on the cotton and wool fibres. Sulphuric acid with heat may be employed to disintegrate the cotton out of a cotton and wool fabric, while caustic soda may equally well be employed to dissolve the wool from the cotton. Cold strong caustic soda, however, may be employed to mercerize the cotton in wool and cotton goods without detriment to the wool. It is thus evident that absolute knowledge based upon incontrovertible experience is necessary if mistakes are to be avoided and the best results obtained.

CHAPTER III

THE MERCERIZED AND ARTIFICIAL FIBRES EMPLOYED IN THE TEXTILE INDUSTRIES

MERCERIZED COTTON.

THE term mercerization is now applied to a process by means of which cotton yarn or cloth is rendered lustrous and silky in appearance, and the importance of the process has made enormously rapid development since its introduction in 1895. The production of lustre is accompanied by considerable modifications in the structural appearance, chemical character, and dyeing properties of the fibre, and these latter effects of mercerization were first noticed and investigated by John Mercer in 1844.

Mercerization without lustre is carried out by steeping the dry cotton in a cold concentrated solution of caustic soda ($NaOH$ 50° to 60° Tw.) for a few moments, and then well washing to remove the alkali. This changes the microscopic appearance of the individual cotton fibres from that of flattened spiral tubes with thin walls and a relatively large central cavity to that of more or less cylindrical non-spiral tubes with thick walls. The effect in mass of this modification of the fibre is that the threads contract in length, become somewhat thicker, and much stronger; the dyeing properties being also much modified. Chemically the process results in the formation of a definite chemical

compound of cellulose and caustic soda ($C_6H_{10}O_5 \cdot NaOH$) in a state of hydration. On washing, this is decomposed, the alkali being removed and the cellulose regenerated as a hydrate ($C_6H_{10}O_5 \cdot H_2O$) which permanently retains the altered appearance and properties above noted.

The natural shrinkage thus brought about is made use of in the production of *crepon* effects on mixed cotton and wool fabrics.

Lustreing by mercerization is obtained by a very slight modification of Mercer's original process; the shrinkage of the yarn or cloth which would naturally take place being prevented by mechanical means.

"Mercerization" may also be brought about by the use of substances other than caustic soda, *e.g.*, sulphuric, nitric, or phosphoric acid or zinc chloride; the use of these being mentioned in Mercer's original patent. Sodium sulphide has also been proposed, but none of these bodies are of any practical importance in this connection.

The Process.—The essentials of the process are very simple, but for economical and efficient working the following points require attention:—(1) The caustic soda solution should be used at a strength of about 55° Tw. and as cold as possible without artificial cooling; (2) the material must be thoroughly and uniformly impregnated; (3) the material must be kept in a state of uniform tension until the washing has decomposed the alkali cellulose; (4) as much of the caustic soda as possible must be recovered; (5) the cotton must be of long staple and the threads must not be too tightly twisted.

Many different mercerizing machines have been introduced, and their relative success depends upon the degree

to which they satisfy conditions Nos. 2, 3, and 4 specified above, and are economical as regards output and labour required. The soda recovery apparatus is another important feature of a modern mercerizing plant. In this the wash waters are evaporated to mercerizing strength, and the recovered soda is treated with lime to recausticize the portion which has been converted into carbonate during the various operations.

Bleaching and Mercerizing.—If cotton is bleached after mercerization the process of bleaching does not destroy the lustre of the mercerized fibre; but this sequence of operations offers no advantage, and the maximum lustre is always obtained when the material is subjected to as little treatment as possible after mercerization. Treatment with bleaching powder after mercerizing is also liable to rot the fibre by oxidation.

The Dyeing of Mercerized Cotton.—It has already been mentioned that mercerized cotton has a much greater affinity for many mordants and dyes than the untreated fibre. The effect is greatest in the case of cotton mercerized without tension, and diminishes somewhat as the tension is increased, being least marked in fully lustred cotton. The difference in the chemical properties of mercerized and unmercerized cotton is the main cause of their different behaviour in dyeing, but structural or physical change has also a considerable effect.

Irregular mercerization is a frequent cause of irregular dyeing, and special precautions must be taken when the cotton is subsequently to be dyed in pale shades. Some further information regarding the dyeing properties of mercerized cotton will be found in the next chapter, p. 80.

Crimp effects on Cotton are obtained by mercerizing cotton cloth in stripes or other patterns by a printing process, the natural shrinkage of the mercerized portion producing the crimp. If printed and mercerized under tension, lustre patterns may be obtained on cotton cloth.

Crepon effects on Union Cloth.—Wool fibre is practically unaffected by caustic soda of mercerizing strength, and if suitably woven with cotton and the fabric mercerized, the shrinkage of the cotton throws up the wool into loops or knots. Silk-cotton unions may be similarly treated, but require great care in manipulation.

The Schreiner Finish.—This process of increasing the lustre of cotton is so closely connected with mercerizing lustre from the practical standpoint that mention should here be made of it. It consists in subjecting cotton cloth to the action of an engraved steel roller under great pressure. The engraving consists of very fine serrations, numbering 400 to 700 per inch, and these produce optically reflecting surfaces upon the threads which very greatly enhance the lustre of the material. Cotton lustred by mercerization and subsequently treated with the Schreiner calender rivals silk in appearance.

The Production of Mercerized Cotton is by far the most important recent development in the textile trade, having practically enriched it with a new fibre almost as lustrous as silk, and of course much less costly. One of the main defects of mercerized cotton is that its lack of elasticity renders fabrics made from it very liable to crease.

Test for Mercerized Cotton.—A solution of iodine in saturated potassium iodide solution colours both ordinary and mercerized cotton a deep brown. On washing with

water, mercerized cotton changes to a blue black, which fades very slowly on long washing, whereas ordinary cotton rapidly becomes white on washing.

Artificial Silk.

The silk fibre, consisting of the solidified fluid of the silk glands of the worm, is devoid of cellular structure. Wool and cotton, on the other hand, are highly organized fibres from the structural standpoint, being composed of a vast number of individual cells built up in a definite and orderly manner. It is thus impossible to conceive of the mechanical production of a fibre resembling wool or cotton in character; but in its broadest outline the problem of the production of a fibre similar to silk is not a difficult one.

The problem involves two main features—first, the production of a viscous liquid analogous to that naturally existing in the silkworm glands, and, secondly, the mechanical conversion of this into thin fibres.

The second part of the problem offers no insuperable difficulties; in fact artificial silk fibres are now produced which are much finer than those of natural silk (Thiele silk).

The composition of the viscous liquid may be chemically similar to natural silk or may be of an entirely different character. The first artificial filament which resembled silk in appearance was spun glass, from which fabrics of brilliant lustre and considerable softness may be produced. These are, however, of little value, since the fabric rapidly disintegrates on account of the brittle nature of the fibre.

Vanduara Silk is obtained by using gelatine as a basis, the threads, after spinning, being treated with formaldehyde

to render them insoluble in water. It is a beautifully lustrous fibre, and fairly strong and elastic in the dry condition, but if wetted it becomes extremely tender. It is now little, if at all, used.

Gelatine may also be rendered insoluble by the combined action of chromic acid and light, and this has formed the basis of an artificial silk process; but no practical success has been achieved on these lines.

Cellulose Silk.—All the commercially produced artificial silks are obtained by using some form of cellulose as a basis, and amongst these may be mentioned the *De Chardonnet*, *Pauly*, *Lehner*, *Vivier*, *Thiele*, *Stearn* and *Bronnert* silks, which are also known under such names as "*Collodion silks*," "*Glauzstoff*," "*Lustro-cellulose*," and "*Viscose silk*."

Cellulose, the chemical basis of cotton, linen, wood, and the structural portion of vegetable growth generally, is chemically a very inert substance, and only two or three ways of dissolving it are known.

(1) When converted into nitro-cellulose by treatment with nitric acid it becomes soluble in alcohol-ether. The various "collodion" silks are thus produced.

(2) Cellulose is soluble in a concentrated solution of zinc chloride, or

(3) In an ammoniacal solution of oxide of copper.

(4) If cotton is mercerized with caustic soda and treated with carbon disulphide while still saturated with the alkali, it forms a new chemical compound (cellulose thiocarbonate), which is soluble in water and is known as "viscose."

(5) Acetates of cellulose may be produced which are soluble in various solvents.

Each of the first four methods of dissolving cellulose forms the basis of a commercial process for manufacturing artificial silk.

(1) *Collodion Silk.*—This was the original artificial silk, and was first patented by De Chardonnet in 1886. After surmounting many difficulties, due chiefly to the inflammability and lack of strength of the fibre, the process is now a great commercial success, and it is estimated that the output of the various factories totals about 1,000 tons per annum. The chief names connected with this product are those of De Chardonnet, Lehner, and Vivier.

(2) *Bronnert Silk* is made from a zinc chloride solution of cellulose, but this process has not made such rapid development as

(3) The *Cuprammonium process*, which yields the *Pauly*, *Linkmayer*, and *Thiele* silks, which latter is, as regards appearance and handle, almost indistinguishable from natural silk.

(4) The *Viscose Silk* of Cross & Bevan and Stearn is also of much interest.

Properties of Artificial Silk.—The characteristic properties of natural silk which render it so much esteemed as a textile material are its beautiful lustre, softness, elasticity, strength, and covering power, and the ease with which it can be dyed. With regard to lustre the artificial silks exceed the natural fibre, some having almost an undesirable metallic lustre. In softness and general handle most varieties of artificial silk are somewhat deficient, but this defect has recently been entirely overcome by building up the thread of a large number of fine filaments, so that a thread of 40 denier may contain 40 to 80 of such filaments.

Such a product is now on the market (Thiele silk), and its softness and covering power equal that of natural silk. All the artificial silks are, however, somewhat difficult to manipulate in winding and in the loom.

In *elasticity and strength* artificial silks are somewhat deficient even when dry, and when wetted the defect is greatly accentuated. This renders careful treatment in dyeing very necessary.

Dyeing Properties.—The various artificial silks differ considerably in dyeing properties. Collodion silks dye for the most part similarly to natural silk, while Pauly, Linkmayer, and Thiele silks and Viscose silk behave much more like cotton (see Chapter IV.).

The importance of artificial silk as a textile fibre is now recognized, but it is not widely known that the production already amounts to eight or nine tons a day and is rapidly increasing. The price is from one-third to one-half of that of mulberry silk, but will undoubtedly decrease. Fabrics entirely composed of artificial silk have only recently been successfully produced, but it has for some time been largely used as weft yarn, and still more largely in the production of plushes and trimmings.

CHAPTER IV

THE DYEING OF TEXTILE MATERIALS

Dyeing processes vary in character according to the textile material operated upon and the nature and properties of the colour desired. Thus, *e.g.*, the production of scarlet shades on wool and on cotton requires entirely different processes, and the method used in producing a blue on wool with indigo is quite distinct in character from that required for dyeing logwood black.

Many (but by no means all) of the processes used in cotton dyeing are carried out without heat. Silk is usually dyed in lukewarm baths, while wool dyeing processes are usually conducted in boiling baths. Silk is almost invariably dyed in the hank or warp; cotton in the form of hank, cop (or bobbins), warp, or cloth; while wool is dyed at all stages of manufacture, viz., as loose wool, sliver, hank, warp (occasionally), and in piece.

In all cases the materials are applied to the fibre in aqueous solution, from which they are withdrawn either partially or completely by simple absorption or by some chemical action of the fibre. So-called "dry dyeing" is a special process used by garment dyers in which benzine or other similar organic solvent is employed instead of water. The object of the process is to avoid the removal of the stiffening materials in the fabrics.

The number of distinct dyes now on the market is very large (upwards of 1,000), and with a few notable exceptions they are all chemically derived from coal tar products. Of the natural dyes still commercially used, indigo and logwood are much the most important; but a few others, such as cochineal, fustic, and orchil, find a more limited application.

In addition to the dyestuff itself, various chemical bodies are required in dyeing operations, some being essential constituents of the ultimate dyed colour (mordants), and others merely aiding the solution or fixation of the dye (assistants). In this short summary of dyeing operations no exhaustive treatment either of dyestuffs, mordants, or assistants is possible; but many examples of each will be incidentally mentioned.

Mordants.—This term is applied to substances which serve a double purpose, viz., they unite both with the fibre and with the colouring matter, and thus fix the latter on the fibre, and at the same time the new chemical compound formed by mordant and dyestuff has frequently an entirely different colour to that of the dyestuff itself, being in fact the real dye. The mordant is usually applied in a separate process before dyeing; but with an increasing number of dyes the mordanting comes last, and in some cases the mordant and dye are used together. The chemical nature of the mordant must depend upon that of the dyestuff. In wool dyeing certain metallic salts are largely used (bichromate of potash, alum, sulphates of copper and iron), whereas in cotton dyeing tannin matters are largely used as mordants for the basic dyes. In dyeing silk, dyestuffs which do not require mordants are chiefly employed.

Assistants.—A large variety of acids, alkalies, and salts

are used for various purposes in dyeing. The acids chiefly employed are sulphuric (vitriol), acetic, and formic, all of which are used with acid dyes. Carbonate of soda (soda ash), caustic soda, and ammonia are the chief alkalies used, and sodium chloride (common salt), sodium sulphate (Glauber's salt), and many other salts are employed in various cases as additions to the dye-bath. The *rôle* of assistants is very varied and cannot be shortly summarized.

Dyestuffs.—In view of the enormous number of dyestuffs it is impossible to deal with them without adopting some method of classification, and grouping them according to method of application, the following may be distinguished:—Group (1) *Mordant dyes*; (2) *Acid-mordant dyes*; (3) *Acid dyes*; (4) *Direct cotton dyes*; (5) *Basic dyes*; (6) *Dyes applied by special processes.*

(1) *Mordant dyes.*—With some important exceptions this group includes the "fast" dyes. Many of them are extremely resistant to the action of the light and to such processes as washing and milling (fulling). They must be used in conjunction with some metallic mordant, such as bichromate of potash or alum, and can be applied to all fibres, though they are chiefly used in wool dyeing.

Example.—Boil the wool for one to two hours in a solution of 3 per cent. bichromate of potash (calculated on the weight of the wool); wash and boil in a separate bath with the dyestuff.

Dyes of this group are not, as a rule, capable of producing bright colours, being chiefly used for blacks, navies, browns, olives, etc. The group includes the alizarin, anthracene, chrome and diamond dyes, logwood, madder, and many others.

(2) *Acid-mordant dyes.* — These dyestuffs have very similar properties to the last group, but are applicable only to wool. They are of increasing importance and include the acid-alizarin and acid-anthracene dyes, the cloth reds, etc. They are applied in an acid bath and subsequently treated with a metallic mordant.

(3) *Acid dyes* are largely used both in wool and silk dyeing, but are not applicable to cotton. They are not used in conjunction with mordants, but are dyed direct with the addition of 2 to 4 per cent. (sulphuric or formic) acid to the dye-bath. They vary considerably in regard to fastness to light, some being very fast and others comparatively fugitive; but as a class they are not so fast as groups (1) and (2). They are also more readily affected by washing and milling (fulling).

This group is a very numerous one and comprises a complete range of shades from the brightest primary colours to black.

(4) *The Direct Cotton dyes.*—These, as their name implies, have the special property of dyeing cotton without the aid of any mordant. Many of them are also used on wool, on which fibre they produce shades which are fast to milling. They are little used on silk. The method of application to any fibre is very simple, the only addition required being salt or Glauber's salt, with or without a little soda ash. By certain methods of after-treatment ("saddening" and "developing") some of these dyes are rendered much faster than when dyed in the direct manner. Practically the same complete range of shades is obtainable with the direct cotton colours as with the acid colours. As examples of this group may be

mentioned the benzo, diamine, mikado, titan, and hessian dyes.

(5) *The Basic Colours.*—This group is numerically smaller, and in range of colour less extensive, than the groups of mordant, acid, or direct cotton dyes. It includes, however, the most brilliant dyes known, rhodamine pink, auramine yellow, malachite green, methylene blue, magenta, and methyl violet being well-known examples. The basic dyes (with few exceptions) are not used on wool, since they are apt to rub (smear). On silk they are dyed direct, with the addition of a little soap, but cotton requires to be previously mordanted with tannic acid or some form of tannin matter. The most serious defect of this group of dyes, as a class, is that they are fugitive to light.

(6) *Dyes applied by special processes.*—**Indigo.**—This is the most important of all dyestuffs, still retaining its pre-eminence in spite of the large number of competitors and substitutes which have been introduced. It is used very largely both on wool and on cotton materials, but only rarely on silk. Being quite insoluble in water, a special method of application is necessary, and this is the same in principle whether used for wool or cotton. The process is based upon the fact that when indigo is acted upon by what are chemically known as reducing agents, the blue insoluble substance is converted into a colourless body which is soluble in alkalies. The necessary ingredients in an indigo vat are thus the indigo, some alkali (usually lime), and some reducing agent; and the various kinds of vats in use differ chiefly in the nature of the latter. In the "woad vat," which is largely used in the dyeing of wool materials, the reduction is due to a specific bacterium which

is introduced by the woad; certain other substances, such as bran, madder, molasses, etc., being also necessary to supply foodstuff for the bacteria. This vat is used warm, and when once "set" may remain in use for several months, being systematically replenished with indigo, etc. The "hydrosulphite vat" contains indigo, lime, and hydrosulphite of soda, and may be used warm (for wool) or cold (for cotton). The "copperas vat" is made up with indigo, lime, and copperas (ferrous sulphate) and is used for cotton.

The process of dyeing in the indigo vat consists in saturating the material with the vat liquor and, after squeezing out the excess, exposing the material to the air, when the colourless reduced indigo becomes rapidly re-oxidized on the fibre into the original blue indigo.

Synthetic or "artificial" indigo, being chemically identical with natural indigo, is applied in the same manner. There are now several distinct but closely associated synthetical dyestuffs in addition to the true "artificial indigo." They are all dyed in similar manner, but yield a variety of blue, purple, and red shades.

In dyeing dark indigo blues on wool materials it is usual to "bottom" the wool with some other (cheaper) colouring matter before dyeing in the vat. Frequently also the indigo is "filled up" or "topped" after vatting, either with the same object or in order to impart a "bloom" to the colour. Heavy shades of pure vat blue are rarely met with.

Well-dyed indigo vat blue produces extremely fast shades on wool. It retains its fine bloom and brilliancy almost indefinitely, and washing does not affect it in the least. It

also withstands sea air, but of course, if "bottomed" or "topped," the associated dyestuffs may be affected. The one defect of vat blue is that the colour "rubs off." This cannot be entirely prevented, but the more skilfully the dyeing process is carried out the less noticeable is the defect. Indigo blue is less fast to light on cotton than on wool.

Aniline black is another dye which requires a special method of application, being of such an insoluble and chemically resistant nature that the only practicable method of using it is to actually produce it on the fibre by suitable chemical reactions. It is the most brilliant, dense, and permanent black which can be produced on cotton, and is dyed, chiefly on cotton yarn, in large amount. It is little used on wool or silk. Aniline black is obtained by the oxidation of aniline, a basic substance ($C_6H_5 \cdot NH_2$) produced from the coal tar hydrocarbon benzene (C_6H_6). A bath is prepared containing aniline oil, hydrochloric (or other) acid, and some suitable oxidizing agent. The cotton is saturated with this liquor and then "aged" (hung in a warm, moist atmosphere) or otherwise subjected to oxidizing conditions.

As in the case of indigo, aniline black is apt to "rub off" if badly dyed. Another defect which can be avoided by skilful dyeing (but only in this manner) is tendering of the fibre. This may be due either to undue acidity of the bath or to oxidation of the fibre.

Aniline black is a very "fast" colour. It withstands "cross-dyeing" perfectly and is also fast to light, washing, milling, etc. If dyed in a special manner it is unaffected by the very severe processes involved in cotton bleaching

("bleaching black"). It is most readily attacked by reducing agents, such as sulphurous acid, which turn it green, and long exposure to the atmosphere of a room where gas is burnt may thus cause "greening."

The Sulphide dyes have only within the last few years attained to the great importance which they can now claim. The group includes many blacks, blues, dark greens, browns, and yellows, but at present a good red of this series has not been put on the market. With the exception of aniline black, they are now the chief dyes used to produce fast colours on cotton. They are most conveniently dyed on warps, but are also used on pieces and hanks. The general method of application is to dissolve the dyes (which are insoluble in water) in a solution of sodium sulphide, some sodium carbonate and Glauber's salt being also frequently used in the dye-bath. The baths are used warm, and dyeing must take place below the surface of the liquor.

A very serious defect of the sulphide dyes is that cotton dyed with them is liable to become tender (rotten) on storing. This is due to the slow development of sulphuric acid by oxidation of the sulphur associated with the dyestuff. The defect is most liable to occur in stoved union goods. The tendering may be prevented by any treatment which leaves the goods in a permanently alkaline condition.

The sulphide dyes are fast to "cross-dyeing" and to alkalies and milling. Vidal black was the first important dye of this series, and as further examples may be mentioned the "immedial," "katigen," "kryogen," "cross-dye," "sulphur," "pyrogene," "thiogene," "thionol," "thional," and "pyrol" blacks and colours.

The Ingrain dyes.—The term "ingrain" as applied to dyes is a very old one. It is now used to designate a certain series of cotton dyes—chiefly reds—which are produced on the fibre.

Para (or paranitraniline) red is produced on yarn, warps or pieces, by first impregnating the cotton with a colourless solution of naphthol, drying and "developing" by passing through a solution of paranitraniline treated with nitrous acid. The red is produced instantaneously. It is a very brilliant and fairly fast colour and is largely used as a substitute for Turkey red.

Primuline red is a somewhat similar dye, but is produced in the reverse way. The cotton in this case is dyed with primuline (a direct yellow dye), then treated with nitrous acid, and the yellow colour "developed" into a red by treatment with naphthol.

There are also black, blue, purple, brown, and yellow dyes belonging to this series, but they are not much used.

Turkey red has somewhat of the same pre-eminence as a red on cotton as indigo vat blue has on wool. Its production is a special branch of dyeing, carried on in special works in a few districts (Manchester and Glasgow). It really belongs to the class of mordant dyes, but is produced in such a special manner that it may more fittingly be mentioned in the section of "special dyes." The cotton, in yarn or piece goods form, is first treated with olive or castor oil, then mordanted with alumina, and finally dyed with alizarin. Many subsidiary processes are necessary in order to thoroughly fix the colour and develop its full brilliancy. Well dyed Turkey red is a bright scarlet colour and is very fast to all influences.

Water used in Dyeing.

In no industry is a plentiful supply of pure soft water of more importance than in dyeing, the use of unsuitable water resulting not only in considerable waste of material, but also in bad work. Perfectly pure water is, however, never available in sufficient quantity, since it is not found in natural sources, and thus the difference in the quality of various water supplies is largely one of degree. The chief impurities naturally present in water are the carbonates, sulphates, and chlorides of lime and magnesium, which impart to the water the property of forming a curdy scum with soap, usually termed "hardness." A "soft" water is most suitable for dyeing, but "permanent hardness," which is due to sulphates and chlorides, is much less harmful in dyeing than the "temporary hardness" caused by carbonates. In wool scouring or any other process in which soap is used, both kinds of hardness are equally injurious, and the lime-soap curd which is produced adheres to the fibre and causes much subsequent trouble and damage in dyeing and finishing operations. The wastefulness of hard water is well illustrated by the fact that 1,000 gallons of water of only 10° hardness will destroy and render not only useless, but dangerous, 15 to 20 lbs. of ordinary soap.

Iron is a not infrequent impurity in water supplies, particularly such as are obtained from coal measures, and water containing iron is totally unfit for use in a dye-house, since iron has a dulling and darkening effect on many dyes.

Water of less than 5° of hardness may be considered as a good quality for dyeing, particularly if the hardness

is mainly "permanent." If the only available supply exceeds 8° or 10° in hardness it should be "softened" by chemical treatment before use. This can usually be done at a cost not exceeding 2*d.* to 3*d.* per 1,000 gallons.

The organic impurities in water have usually little effect on dyeing processes, unless the water is contaminated with the refuse from other works.

Reference may also be made to the desirability of using soft water for steam-raising in order to prevent the production of "boiler scale."

Interdependence of Processes.

In order to produce the best possible result it is not only necessary that the raw material of which a textile fabric is composed should be of good quality, but that all the various operations involved in its manufacture should be carried out with proper skill and care and with a due regard to each other. Thus the carder or comber, the spinner, the manufacturer, the dyer, and the finisher should each work with a sufficient knowledge of the bearing of his particular operation on the other processes of manufacture.

The high degree of specialization in the textile trade in some districts renders co-operation between the various branches specially necessary and at the same time specially difficult. This frequently causes great trouble to the dyer who may be merely instructed to match a given shade without being given information as to the processes which the material will afterwards undergo. This lack of information makes it impossible for him to select the most suitable method of dyeing to fit the conditions, and an

element of risk is introduced which is entirely unnecessary and could be eliminated.

Processes Preliminary to Dyeing.

In order that bright, clear, and fast colours may be produced in dyeing it is necessary that the textile material, whatever its character, should be thoroughly cleansed from all grease, dirt, and other impurities before the dyeing process is carried out. The treatment requisite for this varies. In the case of wool the cleansing process is known as "scouring," while the "bleaching" operation has a very similar object in the case of cotton, and silk is "boiled-off."

Wool Scouring.—Raw wool is naturally covered with a preservative greasy matter, termed "yolk," to which also adheres a considerable quantity of sand, dirt, and other foreign matter; the amount of pure wool varying from 30 to 80 per cent. of the weight of raw wool. The "scouring" or "washing" of raw wool has the object of removing these impurities, and the process is carried out by treating the wool with warm (not hot) solutions of soap with the addition of ammonia or carbonate of soda. This emulsifies the yolk, the sand, etc., being then readily washed away. Scoured wool is usually oiled before carding or combing, and this oil, together with dirt, etc., contracted during the various stages of manufacture, must be removed by a second scouring operation before yarn or piece dyeing.

Efficient scouring has a great influence on the dyer's work and on the final appearance and quality of the pieces. If wool is not properly scoured the colour is apt to be dull

and to "rub off," or may be uneven or show dark or light spots. On the other hand, if the scouring is too severe the fibre has a diminished lustre, a yellowish colour, and a harsh feel.

"Boiling-off" Silk.—This operation consists in treating the raw silk in (at least) two successive soap baths; the first one at a medium temperature, and the second being used boiling. It has the object of developing the lustre and soft feel of the silk by removing the "silk gum" with which the fibre is naturally encrusted. Silk may, however, be dyed "in the gum" or only partially boiled-off.

Cotton Bleaching.—The amount of impurity naturally present in raw cotton is small, but the raw fibre is not in a suitable state to be dyed, as the "cotton wax" present renders the fibre very non-absorbent. "Bleaching for white" is carried out by treating the raw cotton successively with boiling lime-water, boiling caustic soda, and cold dilute bleaching powder solution, with intermediate treatments with cold dilute acid and many washings. Goods which are to be dyed need not be treated with bleaching powder, excepting in the case of pale and delicate shades, but the earlier operations are always necessary.

Wool Dyeing Processes.

When a fabric entirely composed of wool is dyed in the piece it is obvious that a plain colour only can be obtained. If the design of the cloth includes differently coloured threads, the wool must be dyed before weaving, *e.g.*, as yarn; while certain effects (mixtures, etc.) can only be obtained by spinning together differently coloured *fibres* into the same yarn.

This last-mentioned case necessitates the dyeing of the wool in the form of sliver or of loose wool.

The form in which the wool is dyed (whether as loose wool, sliver, yarn, or cloth) greatly influences the choice of dyes to be used. Some dyes produce good, fast shades, but tend to dye unevenly; and such may be used for loose wool where any irregularity disappears in carding, spinning, etc., but are inadmissible in piece dyeing where absolute evenness of shade is essential. On the other hand, the cloth is not scoured after piece dyeing, and, therefore, dyes may be used which would be injured by the scouring process. Loose wool, however, must be dyed with dyes which will withstand scouring.

Dyeing of Loose Wool.—Loose wool may be dyed in square wood or stone vats heated by steam pipes, or in circular iron vats heated externally by fire. The wool must be stirred occasionally with poles to equalize the action of the dye liquor, but since this tends to felt it, discretion is necessary. Loose wool may also be dyed by packing it into perforated receptacles which are either moved about in the hot liquor or through which the liquor is circulated by means of a pump. These newer mechanical processes are now largely used, as they leave the fibre in a free and open condition.

Slubbing (Sliver).—After carding or combing, the thin film of wool fibre is "condensed" into a ribbon of sliver, and may be dyed in this condition either in the form of hanks or wound into balls (tops). At this stage of yarn production the fibres have little coherence, and the hanks or tops require careful treatment. Tops are dyed in an apparatus in which mechanical circulation of the liquor is

provided for, but hanks of slubbing may be treated in the same way as yarn.

Yarn Dyeing.—Yarn may be dyed by hand or by machine. In the hand method the hanks are hung on sticks which rest across oblong vats containing the dye liquor. The hanks are systematically moved about in the liquor and pulled over the sticks. Dyeing machines are also largely employed, the hanks being mechanically moved about in the liquor, or the liquor mechanically circulated through the hanks.

Piece Dyeing.—In this case revolving rollers cause the pieces to travel through or move about in the dye liquors. The pieces run either at full breadth (dyeing in open width) or gathered together as a thick strand (dyeing in rope form), according to the nature of the material.

"**Woaded Colours.**"—This term implies that the wool has been dyed in the indigo vat. A woaded blue should be dyed with indigo alone, but in the case of woaded blacks, greens, and browns the indigo is necessarily combined with other dyes. The term has lost most of its significance since the introduction of the alizarin and other fast dyes.

Blacks on Wool.—*Logwood blacks* are very usual. The wool is mordanted with bichromate of potash and dyed with logwood in a separate bath, a small amount of yellow dye being used to neutralize the blue of the logwood. Beautiful blacks are thus produced, but they have the great defect of turning greenish during long wear of the material. *Alizarin blacks* are obtained by dyeing with a mixture of alizarin dyes or chrome mordant. They do not "green" in wear. Both logwood and alizarin blacks are fast to milling and scouring. *Acid-mordant blacks* (anthracene

acid black, diamond black, etc.) are dyed with the addition of acid and are afterwards chromed. They are fast to all influences. *Acid blacks*, such as naphthylamine and Victoria black, are dyed with the addition of sulphuric acid. They are fairly fast to light, but are not suitable for goods which are to be heavily milled.

Dark Blues, Greens, and Browns on Wool.—These may be obtained by using dyes of any of the various groups mentioned under blacks.

Bright Blues, Greens, Reds, Yellows, and Fancy Colours are chiefly dyed with acid dyes.

Cotton Dyeing Processes.

Cotton is mainly dyed in the form of hanks of yarn and warps, less usually as piece goods. The dyeing of cotton on spools or cops is now rapidly extending, two types of machines being in use. In one type the cops are placed on perforated or grooved skewers and the dye liquor forced through by a pump (skewer dyeing). In the other type the cops are closely packed in a tank, compressed, and the liquor forced completely through the whole mass (pack dyeing). In warp dyeing a number of warps pass side by side continuously through a series of vats containing the necessary mordanting or dyeing liquors.

Occasionally weft yarn is dyed in lengths, as in the case of warps the yarn being subsequently rewound on to weft bobbins. This cannot be recommended, as it is not unusual for warps to be somewhat darker in colour at one end than at the other, and when rewound this may produce a stripy effect in the piece. Cotton in the form of piece goods is dyed in the open width or rope form, usually the former.

The dyeing properties of cotton are quite different from those of wool, and therefore the processes and materials used in the two cases are to a large extent different. Cotton has little affinity for metallic mordants or for dyes belonging to the mordant, acid, or basic groups. It has, however, a definite affinity for tannic acid and for colouring matters belonging to the class known as "direct cotton dyes." Cotton is dyed largely with this group, but the dyed colours, though bright and in some cases fast to light, are not fast to washing with soap. Many of these direct dyes are also affected by acids. A considerable number (but not all) of the direct dyes may be rendered satisfactorily fast by an after-treatment with metallic salts or by "diazotizing and developing," this applying principally to dark browns, blues, and blacks.

Fast Blacks on Cotton.—There are two ways of producing exceedingly fast blacks on cotton, viz., by dyeing it an "aniline black" or with a "sulphide black." Both are largely used, the latter chiefly for the warps of pieces which are afterwards "cross-dyed" (see Union Dyeing). Aniline black is somewhat more costly than a black produced by sulphide dyes, but is considered superior in body, tone, and brilliancy.

Fast Colours on Cotton.—Dark blues, browns, and greens, and a variety of greys, buffs, and pale fancy shades, are also obtained by means of sulphide dyes, but there is as yet no bright red belonging to this group. The fastest bright red on cotton is Turkey red, which is obtained by oiling the cotton, then mordanting with alum and dyeing with alizarin. Para red (paranitraniline red) is also very bright and fairly fast. It is produced by saturating the cotton

with an alkaline solution of beta-naphthol, then drying and passing into a diazotized solution of paranitraniline. In this case, as in aniline black, the dye is actually formed on the fibre.

Cotton is also largely dyed with indigo in a similar manner to wool, but the vat is used cold and a chemical reducing agent is used (ferrous sulphate or sodium hydrosulphite).

Fast browns, drabs, etc., are largely dyed with catechu.

Basic Colours on Cotton.—These dyes are fixed on cotton by mordanting the fibre in a solution of some tannin matter (sumach or myrabolans), then "fixing" in a solution of some suitable metallic salt (tartar emetic or stannic chloride), and finally dyeing. The basic colours comprise a series of extremely bright reds, yellows, blues, greens, and violets, as well as many duller colours. As a class they are fugitive to light, but there are exceptions to this.

Dyeing of Mercerized Cotton.—The general dyeing properties of mercerized cotton are similar to those of ordinary cotton, but the affinity of mercerized cotton for the direct dyes, the sulphide dyes, indigo, and para red is much increased, and the shades obtained by using a certain strength of dye solution are much deeper and richer. On the other hand, mercerized cotton dyes less easily than ordinary cotton with basic colours. If the cotton has not been evenly mercerized it is impossible to produce level shades in dyeing.

Union Dyeing Processes.

Union goods composed of cotton and wool require special methods of dyeing. A common process is to dye the cotton

in the warp, the dyed cotton being then woven with undyed wool weft. The pieces are then "cross-dyed" with acid dyes which colour the wool only. The cotton warp must, of course, be dyed with colouring matters (such as the sulphide dyes) which are unaffected by boiling dilute acid. Another process largely made use of in low-class unions is to first dye the wool in the piece with acid dyes, and then to "fill up" the cotton by mordanting with tannin and dyeing with a basic colour, the whole of the cotton treatment being conducted in the cold in order to avoid staining the wool. When a uniform shade is required on both fibres the union material may be dyed with direct cotton dyes which colour both wool and cotton.

Silk Dyeing Processes.

Silk is always dyed in hank form; and closely associated with the dyeing is the so-called weighting process. Silk has the peculiar property of absorbing certain metallic salts and other bodies (tannin, glucose, etc.) to an enormous extent without injury to its lustre, and by suitable treatment it can in this manner be weighted to such a degree that 1 lb. of raw silk produces 2 to 3 lbs. of dyed and weighted silk. This weighting process is very general, 25 to 50 per cent. of added weight being usual. The practice is, however, greatly to be deprecated, as it injures the wearing properties of the fibre. Pure silk has excellent lasting properties, while weighted silk will gradually become rotten merely by storage.

Wild Silk (Tussur Silk) is very difficult to dye, and a good black on tussur can only be produced by a few

dyers. It dyes readily with basic dyes and fairly well with acid dyes.

Reeled Silk (Mulberry Silk) has, generally speaking, similar dyeing properties to wool. It is chiefly dyed with acid or basic dyes without mordant, and there is no difficulty in obtaining a variety of brilliant colours on this fibre. In boiling baths wool dyes deeper colours than silk, but at low temperatures the relative affinity is reversed, and an intermediate temperature may therefore be usually found (varying with each dye) at which the two fibres dye equally.

Silk is rarely dyed with indigo or with mordant dyes, excepting in the case of blacks.

The dyeing of black silk constitutes a special branch of the dyeing trade and needs considerable experience.

The Dyeing of Artificial Silk.

The artificial silks, being essentially constituted of cellulose, have dyeing properties similar to those of cotton, but the various kinds of artificial silk differ considerably in this respect. On account of the low tensile strength of many artificial silks when wetted, great care is required in dyeing these fibres. They are best dyed at a comparatively low temperature with basic dyes (without mordant) or with direct cotton dyes.

Colour Matching.

In dyeing any material to match a given shade great care is required to ensure that the two will match under all conditions. If the "matching off" is done by gaslight the two may be quite dissimilar when viewed by daylight. This

well-known fact is due to the different optical properties of the various dyes. Two blue dyes, for example, may appear identical in hue, but when each is mixed with the same amount of the same yellow dye the resulting greens may differ considerably. If examined spectroscopically the two blue dyes will be found to have different absorption spectra, and this is the fundamental cause of their different behaviour in mixtures or when viewed in different lights. The special optical properties of the various dyestuffs are thus of great importance in "matching off" or dyeing to shade. Equally important is the character of the light by which the colours are viewed, and the light reflected from a white cloud into a window with a north aspect is considered the most suitable. The near presence of a red brick wall or any other coloured surface is quite sufficient to disturb an accurate match; direct sunlight or a deep blue sky being also fatal in matching certain greys, drabs, etc. The use of a perfectly uniform light of the same character as a north daylight thus greatly simplifies the accurate matching of colours.[1] The difficulties caused by the different absorption spectra of dyes can only be eliminated by a spectroscopical examination of each, or by using in bulk dyeing the same dyestuffs as were employed in dyeing the pattern which is being matched.

Fastness Properties of Dyes.

That some colours are "fast" and others are "fugitive" to light is a matter of as common knowledge as that some will withstand washing much better than others. These

[1] Such a light is to be found in the "Dalite" lamp of Dufton & Gardner.

differences are inherent to the nature of the dyes and are not (usually) due to defects in the methods of application. Thus the proper selection of dyes is of the greatest importance to the production of satisfactory results. It is obvious, for example, that material which is to be used for stuff curtains should be dyed with dyestuffs which have good fastness to light, fastness to washing being a secondary consideration; on the other hand, yarn which is to be used for making socks or underwear must be dyed with washing-fast colours, the effect of exposure to light being here less important. Again, in the case of woollen goods which are heavily fulled (milled), if yarn dyed the colours must be able to withstand that somewhat severe operation, and cotton warps which are made up with wool weft and then "piece dyed" must be dyed with colours which will not be affected by boiling dilute acid. Each case must thus be specially considered from this point of view as well as regards the question of producing the desired colour.

Tables have been drawn up showing the fastness properties of the various dyestuffs as regards light, milling, scouring, cross-dyeing, rubbing, washing, steaming, hot-pressing, etc., but it is impossible to usefully summarize such lists, and on this point manuals of dyeing must be consulted.

CHAPTER V

THE PRINCIPLES OF SPINNING

It may seem somewhat out of order not to give priority to preparing and combing. But the end must justify the means.

Just as weaving naturally developed before spinning, so did spinning naturally develop before the many interesting and ingenious processes which to-day precede the spinning operation, rendering this operation much easier of accomplishment and vastly more perfect in its results than was the case in the olden days. In dealing with spinning prior to dealing with the preparatory processes, then, we are but following the natural evolution of the processes; and in so doing we have the great gain of knowing exactly what is required—what are the necessary conditions for a "good spin"—and can therefore more perfectly realize the *raison d'être* of the various processes to be subsequently dealt with and described. It might be contended that, following out this principle, weaving should be first dealt with. There is, however, a natural limit beyond which we may not pass without loss rather than gain.

Spinning may be defined as the art of throwing a number of more or less short fibres together in such a way that, being drawn out to form a comparatively fine filament, they grip one another by reason of the twist inserted, and thus form a comparatively firm, strong thread. Thus spinning

primarily consists of the two operations of drawing-out, or "drafting," and twisting. It should at once be noted that this operation is entirely distinct from silk "throwing," which simply consists of reeling the continuous thread of from 400 to 1,600 yards forming the silkworm's cocoon, and throwing or twisting it with one or more threads of similar character to form a firm, stronger thread.

Long Fibre Spinning.—Very brief study of the art of spinning will demonstrate the comparative ease with which long fibres, such as flax, hemp, long wool, etc., may be spun into yarn. Given length and all else is simple. The early recognition of this fact would naturally lead to the preparation of flax, hemp, wool, etc., bundles or slivers so arranged that a continuous band of more or less parallel fibres might be passed into the spinning machine to be given the necessary twist and so be converted into thread. Thus the simplest and consequently earliest form of spinning would consist of some arrangement whereby, after having deftly formed a small band or sliver of fibres by the hand, twist might be expeditiously inserted. Such was "distaff spinning," the process being exactly that just described, with very few conveniences for facilitating speed of production. How long the art of spinning rested in this very inefficient state we do not know, but probably for hundreds of years. Amid the ingenuity with which we of the twentieth century are surrounded from the cradle we cannot well gauge the mental effort necessary to evolve the idea of a continuous spinning process in place of the slow intermittent process. But it came at last, and the flax wheel was evolved. In this the deftly extended sliver of right thickness and regularity was fed continuously by hand

into a flyer revolved by means of a foot-treadle, which, in conjunction with the bobbin upon which the yarn was to be

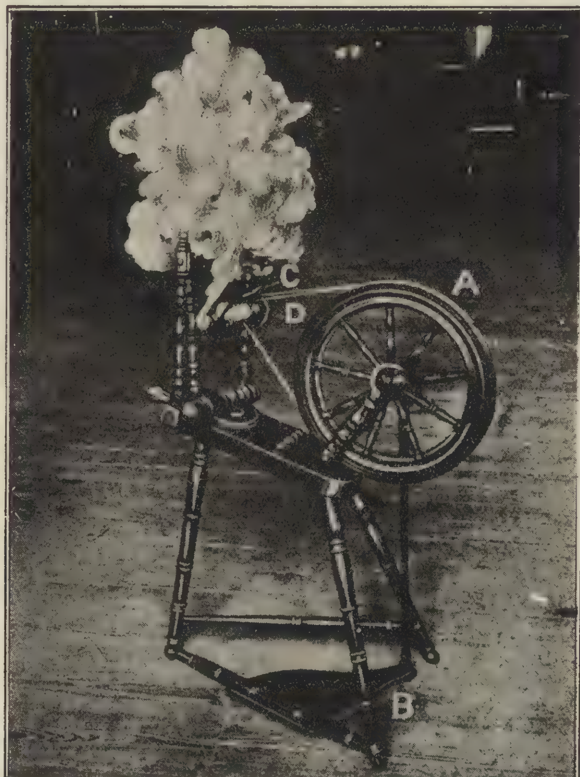


FIG. 9.—Double-grooved Wheel A; Pedal B; Flyer C; Bobbin D.

wound, both twisted it and wound it neatly upon this bobbin. No doubt the difficulty in evolving this arrangement was due to the fact that it is impossible to effect the continuous

feeding in and twisting of a sliver without some means *of winding on to the twisting spindle* the thread so formed, or, on the other hand, of winding the yarn continuously on to a bobbin without some arrangement for the continuous twisting of the same. The bobbin and flyer — practically the fundamental principle of all continuous spinning frames — is really a most ingenious arrangement, and it would not be surprising to find that short fibre spinning on the ordinary simple-spindle hand wheel really preceded this invention. The principle of long fibre spinning is infinitely simpler than the principle of short fibre spinning, but the necessary hand machine for continuous long fibre spinning is much more subtle and complicated than that required for short fibre spinning.

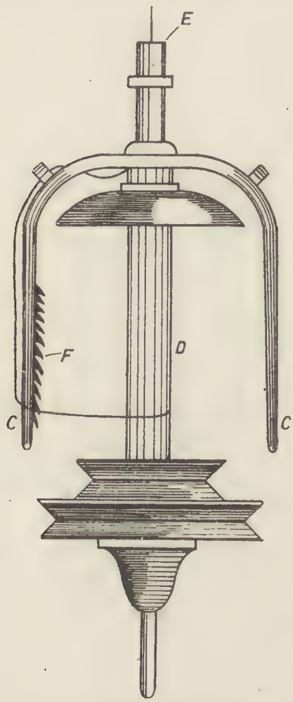


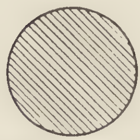
FIG. 9A.—Diagram of Flyer and Bobbin arrangement on the ordinary Flax Wheel.

The "flax wheel" (Figs. 9 and 9a) consists of a double-grooved wheel (A, A) worked by a foot-pedal (B) round which two bands pass, one to the grooved flange on the spindle and flyer (C), and the other to the grooved flange of the bobbin (D), so that as the wheel is revolved by the foot-pedal it in turn revolves both flyer and bobbin. As the bobbin has a smaller grooved flange than

the grooved flange or driving wheel of the spindle, it therefore goes somewhat quicker than the spindle and flyer. The bundle of flax or wool is conveniently placed above the flyer and bobbin, and a convenient or correct thickness of sliver is made up from it and passed through the eye (*E*) of the flyer, round the wing and over a notch or wire (*F*) which directs the thread on to the bobbin. Upon the wheel being revolved, twist is put into the sliver in proportion to the length of sliver delivered to a given number of revolutions of the flyer; and the yarn is wound up in proportion as the bobbin gains upon the flyer. *If no sliver were delivered and the wheel revolved, twist only would be put into the sliver. If all the sliver required were delivered, the bobbin held fast, and the flyer rotated, yarn would simply be wound upon the bobbin. The actual spinning operation comes in between these two extremes.*

The idea of increased production by a continuous employment of both hands and feet would naturally lead to further attempts at increasing production. It would at once be realized that two main developments were necessary, viz., a more speedy means of preparing the slivers to be spun and a greater number of spindles to be worked by hand. This latter idea probably germinated first, as we have fairly early records of a double-spindle flax wheel. Few people, however, would be skilful enough to work this with the condition of feeding the spindles with unprepared slivers; hence little advance was made. The development of drafting rollers by Lewis Paul eventually entirely removed this limitation. How crude the ideas of the eighteenth century were we can only realize by again reverting to the fact that it was supposed that, as with metals, one pair of

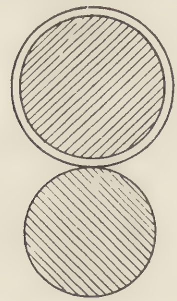
Single Roller.



Points for Consideration.

(1) Size.
(2) Material (foundation and covering).
(3) Fluting.

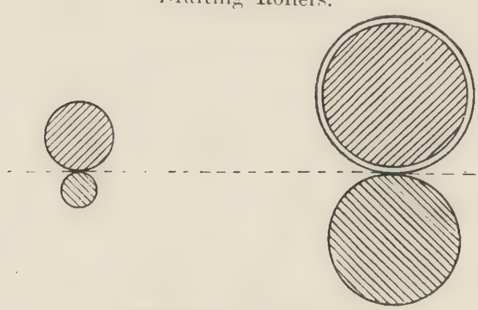
Double Rollers.



Points for Consideration.

(1) Sizes and Relative Sizes.
(2) Material (foundations and coverings).
(3) Fluting.
(4) Method of Weighting.
(5) Method of Driving.

Drafting Rollers.



Points for Consideration.

(1) Relative Sizes of Back and Front Rollers.
(2) Materials (foundations and coverings).
(3) Flutings.
(4) Method of Weighting and Influence on Power Consumed.
(5) Distance apart.
(6) Method of Driving.
(7) Relative Speeds of the two pairs of Rollers.
(8) Inclination of Rollers.
(9) Supports (carriers) between the two pairs of Rollers.

Fig. 10.

rollers would be sufficient to effect the necessary drafting. The development, however, was made, and its utility gradually realized to the full. We can well imagine the interest that Lewis Paul, Arkwright, and others would have in experimenting with rollers and noting the conditions under which they might best be employed for drafting, and it is something to their credit to be able to say that these early workers practically developed in their machines principles and methods which we have not been able to improve upon in principle to any great extent.

A few words on roller-draft will demonstrate the principles employed. Some of the factors of roller-draft are illustrated in Fig. 10. These factors seem comparatively simple, but they are not really so. Take for example the first factor—size of rollers. At least three varying factors are here involved, viz., length of fibre to be drawn, size of roller to give the best conditions of wearing surface, and exact condition of gripping of the fibre desired. Thus in the spinning of short fibres such as cotton the diameter of the rollers should be approximately the length of the fibre (Fig. 11), while in long wool fibres (Fig. 12) there is little relationship of the diameters of the rollers to the length of the fibres, but on the other hand these diameters are decided with reference to grip on the fibre and surface wearing quality. For a $1\frac{1}{2}$-inch staple cotton a $1\frac{5}{8}$-inch diameter pair of rollers is usually employed, while for an 8-inch wool yarn a $1\frac{1}{4}$-inch diameter bottom back roller and a 5-inch top front roller bearing upon a 4-inch diameter bottom roller are usually employed. Here again it will be noted there is an interesting question of "grip." With small rollers the gripping surface will be

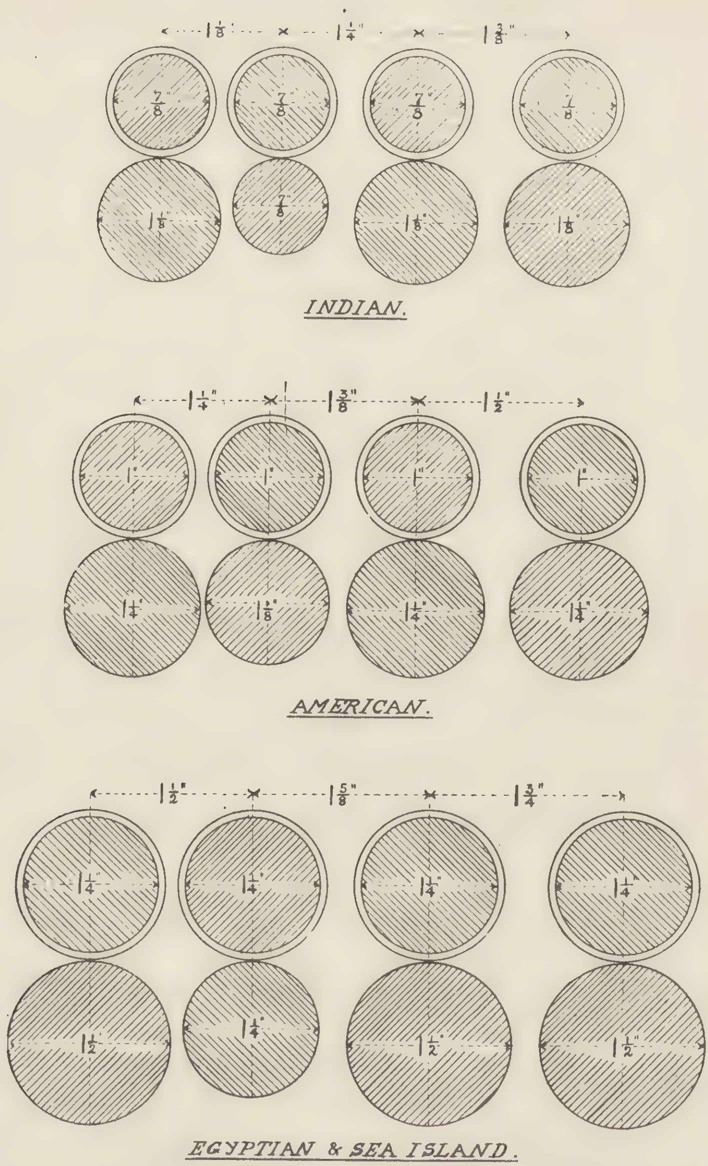


FIG. 11.—Drafting Rollers for Various Lengths of Staples of Cotton.

small, and consequently there is a tendency to "cut." With larger rollers the gripping surface will be much larger, and consequently a firmer grip obtained with less fear of cutting. It will further be evident that it may be very desirable to leave some rollers bare and to clothe other rollers with leather,

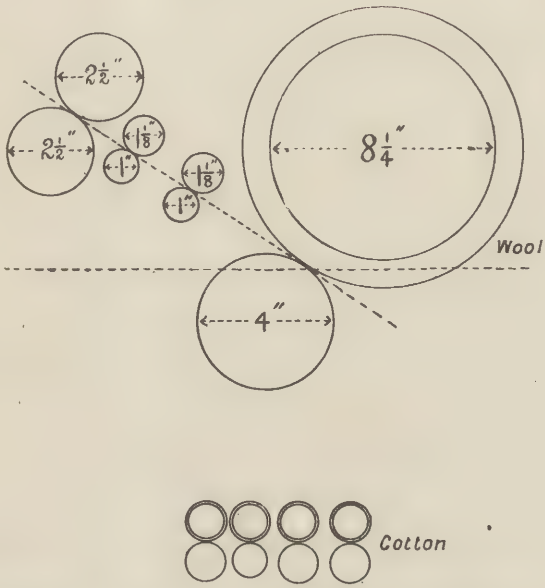


Fig. 12.—Illustrating the Relative Sizes of Wool and Cotton Drafting Rollers.

etc. Now steel rollers may be clothed with leather in two ways, first by running a continuous leather apron between them, or by actually clothing one of the rollers with leather upon a felt or other foundation. Corresponding fluting necessitating rollers of equal size renders the leather apron idea more economical, and in fact necessary, in certain wool

boxes, while in other boxes and frames a large 6-inch roller, leather clothed, fulfils the requirements of the case both from the efficiency and wearing surface or cost points of view.

Again the questions of double metal nip, metal and leather or cloth nip, or double leather or cloth nip are worthy of the most careful consideration. The rollers in a wash-bowl are clothed with wool and wool works wool. But in the case of cotton, leather against metal is applied. Here is a most interesting problem.

Then with reference to the distance apart of the two pairs of drafting rollers most interesting points are to be studied. Take, for instance, an 8-inch wool fibre. If this is passed through rollers 6 inches apart—the front rollers revolving faster than the back rollers—it will probably be broken. If the rollers are exactly 8 inches apart the back pair will give it up just as the front pair take it; while if the rollers are, say, 10 inches apart the fibre must freely ride upon its neighbours for 2 inches after leaving the back rollers before the front rollers take it. The middle condition is the correct one, all cotton drawing rollers being very accurately set to control the fibre as positively as possible without breaking it. But in a well-prepared wool combed sliver or "top" the fibres may vary from 4 inches to 10 inches or 12 inches, while there is also the question of twist in the sliver to be taken into account, twist enabling the drawer, as it were, to work the fibre with the fibre. If it were not for the twist factor and the natural cohesion of wool—save when affected with electricity—wool "top" drawing would be a much more difficult process than it actually is; in fact it would be

necessary to work to the shortest fibre, breaking all the longer fibres, thus consuming power and destroying the quality of length so often required in worsted yarns.

An economical question is involved in the speed at which

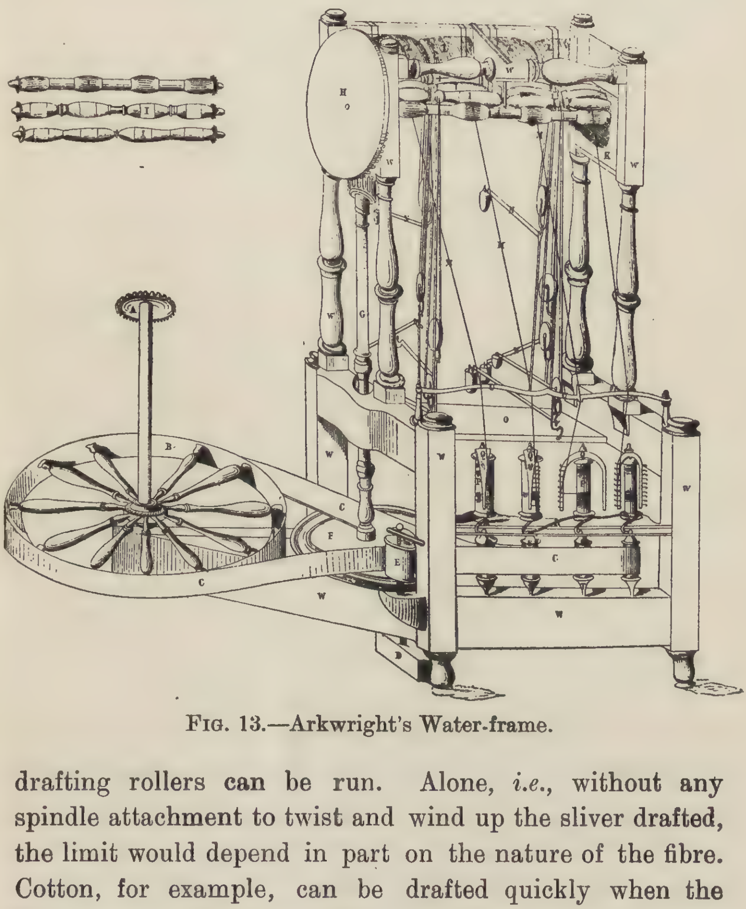


FIG. 13.—Arkwright's Water-frame.

drafting rollers can be run. Alone, *i.e.*, without any spindle attachment to twist and wind up the sliver drafted, the limit would depend in part on the nature of the fibre. Cotton, for example, can be drafted quickly when the fibres are once started sliding upon one another, *but not*

before; and again, air blasts and air friction so affect cotton that they must be very carefully taken into account. There is also a mechanical problem of wear and tear involved, so that altogether this also is really a most interesting, if involved, question.

It will now be realized that given drawing rollers, the flyer and bobbin mechanism, and a reasonably steady driving power, the factors for a successful automatic machine are present. Richard Arkwright was the first to recognize this, and his water-frame was the first machine of any moment effecting the spinning of yarns automatically.

The illustration of Arkwright's "water-frame" (Fig. 13) will explain the general arrangement. The only new problem involved is the relationship of front rollers and spindle. The possible positions of spindle to front rollers are illustrated in Fig. 14, but it should be further remarked that the solution of this problem will in part depend upon the inclination of the drawing rollers. It should further be remarked that probably "gravity" cannot be entirely ignored. So far as relative position goes the relationships shown at *A* and *E* are identical, but it will be realized at once that the force of gravity may make a material difference in the "spin," especially if the sliver is heavy and has not marked adhesive qualities The main point to note, however, is that of limitation of the twist. Anything touching the yarn between the top of spindle and the nip of the front rollers will limit the twist to below this point. Thus in some cases it may be desirable to have such a relative position of spindles and front rollers that the twist runs right up to the nip of the rollers; in other

cases it may be desirable to lay the sliver on the bottom front roller; and in other cases it may actually be neces-

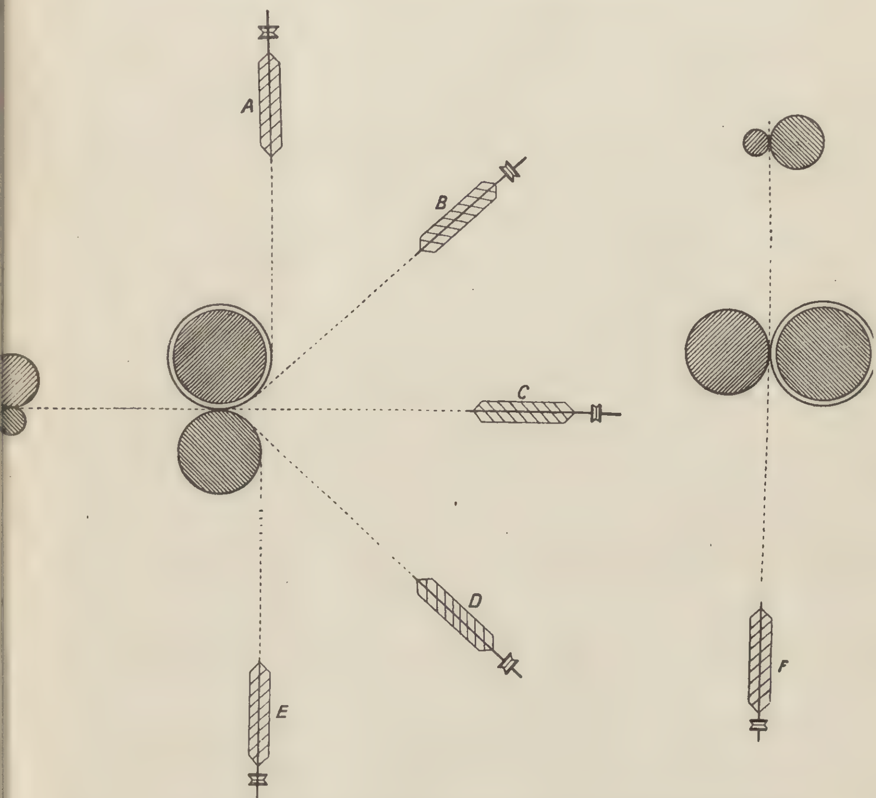


FIG. 14.—Possible position of Spindle in relationship to Drafting Rollers.

sary to introduce what is known as a trap-board with the threefold object of carrying the yarn straight from the nip of the rollers, of centring the yarn above the spindle—as in the cap frame—and of holding the twist in the yarn

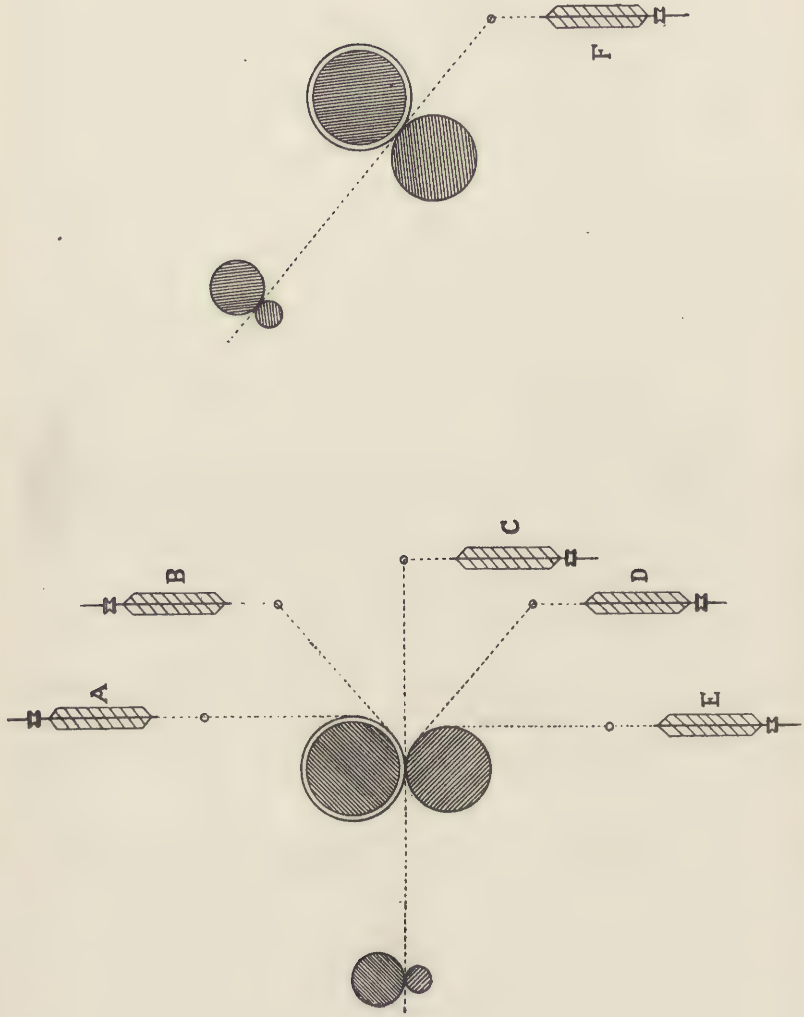


FIG. 14A.—Possible position of Spindle with Guide Eye in relationship to Drafting Rollers.

near to the spindle or cop. This latter point is worthy of very careful consideration, as the holding apart of two threads to be twisted together just above the twisting spindle has a marked effect on the regularity of the twist. The inclination of the spindle also, as will be noted directly, is most important in the woollen mule, and in general hardly receives the attention it merits.

A glance may now be taken at the modifications of the continuous bobbin and flyer principle of spinning introduced since the time of Arkwright.

When it was realized that the bobbin or spindle was the spinning mechanism and the flyer the winder-on, an endeavour was naturally made to simplify this latter, thereby saving expense in construction, effecting a reduction in the consumption of power, easier doffing and quicker running. The labour difficulties in America further forwarded this movement and so the ring frame came into being.

In the modern ring frame the spindle—but in this case without a flyer—is the chief motive factor. The drafted sliver is delivered from exactly above the centre of the spindle, so that upon the spindle being revolved twist is put into the sliver. But how is winding-on effected? Surrounding the spindle is the ring—or, conversely, the spindle passes exactly through the centre of the ring, and upon this ring, suitably controlled by the ring-flange, is a "traveller." The sliver, instead of passing directly to the apex of the spindle, first passes through the traveller and then on to the spindle or bobbin placed on the spindle. The traveller thus acts as a retarder, enabling the spindle to wind up the yarn delivered to it by the front rollers. The

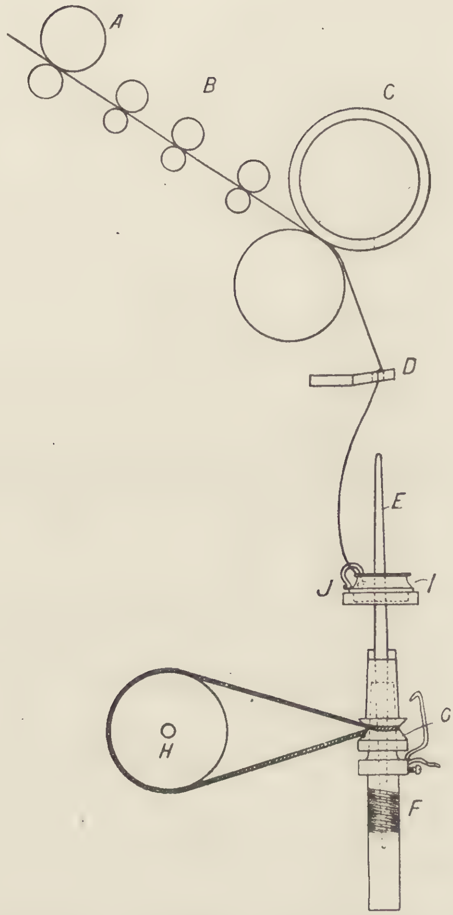


FIG. 15.—Ring Spring Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle; *F*, spindle support; *G*, spindle wharl; *H*, tin drum round which spindle band passes; *I*, ring; *J*, traveller.

yarn is distributed on to the bobbin by the slow movement up and down of the ring-rail, the spindles naturally being fixtures. To ensure high speeds on this machine—say 7,000 to 12,000 revolutions—many spindles of special construction have been designed, some self-balancing, some running in oil, etc. (see Fig. 15).

The development of the ring frame would naturally lead inventors still further afield, and eventually the cap frame was evolved.

The cap frame is very similar to the ring frame, save that the edge of the cap develops, or helps to develop, the friction whereby the bobbin may wind yarn on to itself. As the caps are too heavy to move, the bobbin-rail moves to effect the distribution of the yarn on the bobbin (see Fig. 16). When the cap frame was first tried in Bradford the cops produced were so soft that the yarn could be jerked off the bobbin. This was owing to the fact that the frame was run at 2,800 revolutions per minute "to give it a chance." It was only when the frame was speeded up to 5,000 revolutions per minute that its great possibilities were realized. The cap frame came into the wool district from the cotton district. Why it should be so successful for pure Botany wool and so useless for cotton is again a most interesting question which we have not space to investigate here.

In two important points the supposed automatic spinning frames are not automatic. They neither feed themselves automatically nor do they "doff" themselves automatically. The comparatively large bobbins placed in the creel behind the back rollers of a spinning frame contain so much sliver to be spun that little manual labour is necessary

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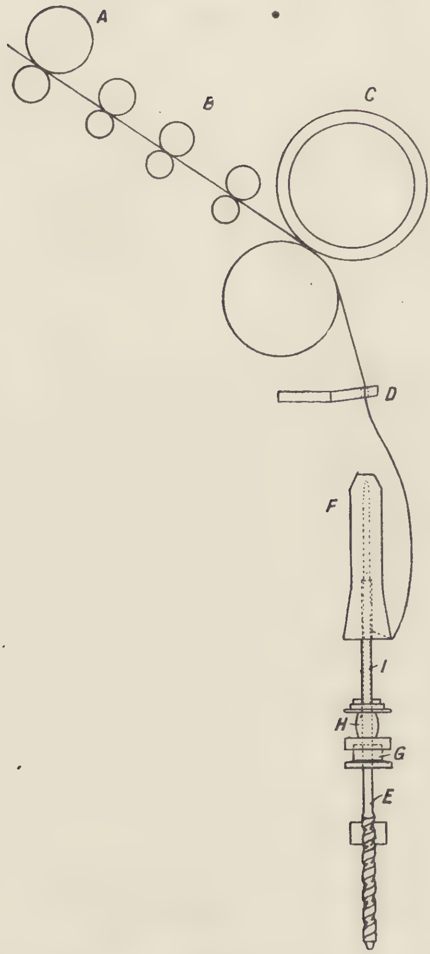


FIG. 16.—Cap Spinning Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle fixed in framework; *F*, cap supported by spindle; *G*, bearing for tube *I*; *H*, wharl round which driving tape passes; *I*, tube upon which bobbin or spool is fixed and carried round.

to keep the frame supplied with slivers or roving to be spun into yarn. Very different is it, however, with the doffing of the comparatively small spools or bobbins upon which the spun yarn is delivered. On an average a flyer frame running on $\frac{1}{40}$'s with 10 turns per inch, will be doffed six times per day of $10\frac{1}{2}$ hours, and a cap frame running on $\frac{1}{48}$'s with 16 turns per inch seven times per day of $10\frac{1}{2}$ hours. With the scarcity in half-time labour the invention of an automatic doffing motion has become imperatively necessary. Messrs. Clough & Co., of Keighley, have successfully employed such a motion on their flyer spinning frames during the past five years, while Mr. W. H. Arnold-Forster, of Burley-in-Wharfedale, has also recently patented such a motion of somewhat novel construction. At first it was thought that given half-time labour such a motion was not required from the economical point of view. From experiments recently made, however, it would appear that it is more than probable that the doffing motion will ultimately supplant half-time labour, being actually considerably more efficient with regard to output. This, however, refers more particularly to flyer frames—the conditions of doffing cap and ring frames being somewhat more complicated. Considering the mechanical problem in a broad way it would seem as though the mechanical problems of doffing are greater than the problems involved in spinning, and that therefore the spinning machine should be made to the doffer and not, as at present, the doffer applied to a machine designed without regard to any such attachment. Of course, to change a machine which, although apparently simple, has been evolved by generations of workers and probably contains more than we have

the least idea of, is a dangerous thing. Still, the result may justify the attempt.

Short Fibre Spinning.—The art of short-fibre spinning would possibly develop some time after long-fibre spinning, being somewhat more involved and of such a nature that it would not so readily be "thought of," but would probably be accidentally "discovered." Briefly, the art of short-fibre spinning consists in supporting the thread or sliver during elongation with twist instead of with rollers. Did spinning simply consist of *twisting* fibres together, then it would be impossible to differentiate between long-fibre spinning and short-fibre spinning. Any difference would then probably lie in the preparation of the respective fibres for the spinning. But the drafting or drawing out of the sliver being necessarily implied, at once emphasizes the difference between long- and short-fibre spinning. For in long-fibre spinning the fibres are of such a length and are arranged so parallel in the sliver that when the spinning twist is inserted it is inserted into a sliver or thread already formed, and of which the thickness is already decided. Whereas in short-fibre spinning the commencement of the final twisting is really a putting in of drafting-twist, *i.e.*, as the twist is inserted the sliver is elongated. But for this drafting-twist the short-fibred slivers to be spun would break. This drafting-twist running into the thinnest sections of the slivers strengthens them, and these becoming the strongest in turn serve as a means to draft the sections which are now relatively weaker. Upon the drafting being completed the elongated sliver is then converted into a true thread by receiving its final complement of twist. So potent is the drafting-twist that it must be exactly adjusted to the

length of fibre being spun, the shorter the fibre and the more drafting-twist, and conversely, the longer the fibre the less drafting-twist, until for long fibres no twist at all is possible, as they bind the sliver too much, under which circumstance roller control must be resorted to. The

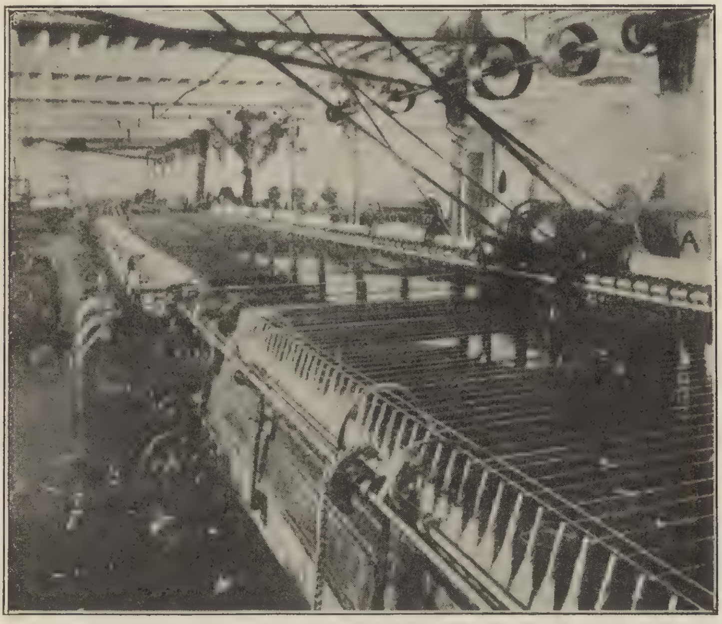


FIG. 17.—General View of Woollen Mule.

principle of spindle-draft is the distinguishing feature of mule spinning, especially woollen mule spinning, producing yarns of marked characteristics which in turn have a marked influence in both the weaving and finishing operations. Again, the method of inserting twist into the slivers on a mule must have some influence upon

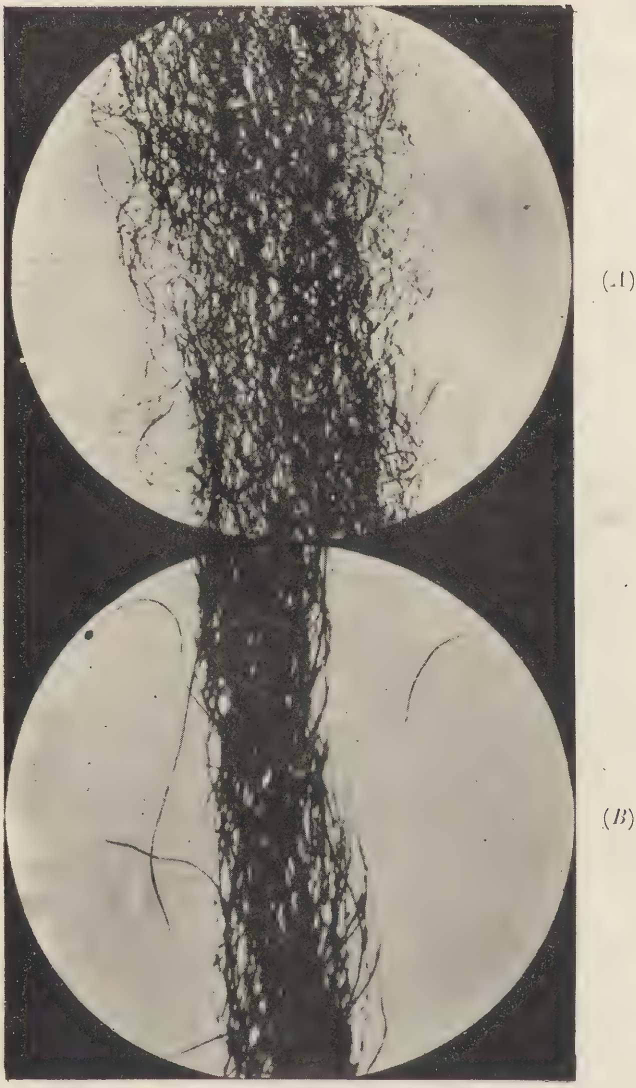


Fig. 17a.—(*A*) Condensed woollen sliver, prior to spinning; (*B*) condensed worsted sliver prior to spinning.

the resultant yarn, though what it exactly is we cannot yet say.

The woollen mule is the perfect short-fibre spinner. In brief, a woollen mule consists of three main parts, viz., the prepared or condensed sliver holder and deliverer, the carriage with its spindles, and the headstock which controls the action of the other two. The condensed sliver (A, Figs. 17 and 17A), brought up from the carding machine on lightly-flanged long condenser bobbins, rests on a delivery roller, and being turned by surface contact is always completely under control. The slivers from these condenser bobbins are passed through a pair of stationary rollers the revolution of which is in accord with the turning of the condensed sliver roller, and both are under perfect control from the headstock, intermittent delivery being varied at will according to the requirements presently to be described. The carriage—carrying from 300 to 700 spindles of any suitable pitch, thickness and inclination, according to the work to be done—is perfectly controlled from the headstock by means of drawing-out and running-in scrolls. The speed of the spindles is also under perfect control so far as drafting-twist and final twist are concerned, and something more than under perfect control when the building up of the cop is in process, as will be explained immediately. One complete spin, starting with the carriage run-in to the delivery rollers, and consequently with the spindle points close to the grip of the rollers, from which the condensed sliver passes direct to the spindle points, takes a few turns round the spindle, and in the shape of spun yarn forms the cop on the spindle, may be described as follows: As the delivery rollers deliver condensed sliver the carriage

with its spindles slowly retreats until it reaches about half the distance of its complete traverse, when the delivery rollers suddenly stop. The carriage, however, goes on towards its full traverse slower and slower, in the meantime the spindles putting in just the requisite drafting or supporting twist which, owing to the nearly upright position and thickness of the spindles, vibrates right along the slivers and ensures distribution in fair proportion to the diameter of the yarn, so that as thin places are strengthened and become strong the thick places are drafted out, and so an equalizing action goes on right throughout the drafting operation. Upon the carriage reaching the extent of its traverse—when drafting is completed—the spindles are turned on to double speed to effect the necessary twisting of the two yards of yarn per spindle, just twisting as quickly as possible. The insertion of so much twist naturally causes a contraction of the thread, and to allow for this a slight return of the carriage towards the delivery rollers is arranged for. Upon the completion of the twisting the spindles are reversed for a few turns—this is termed "backing-off"—to enable the faller guide wire to commence building up the cop from where it left off at the last run-in, and a counter-faller wire, suitably weighted, rises, as a perfectly even tension must be maintained on the yarn, otherwise it "snarls" and forms kinks. The carriage is now freed and commences its run-in under the control of scrolls which, working in conjunction with a quadrant which controls the turning of the spindles, and a "copping-plate" which controls the traversing of the faller-wire, result in a firm, sound cop being built up. Upon reaching the delivering rollers the faller-wire rises; the counter-faller

wire falls and the spindles are free to repeat the cycle of evolutions. Of course a greater or less amount of condensed sliver may be delivered, according to the draft required, more or less drafting-twist may be inserted in accordance with the binding qualities of the material being treated,

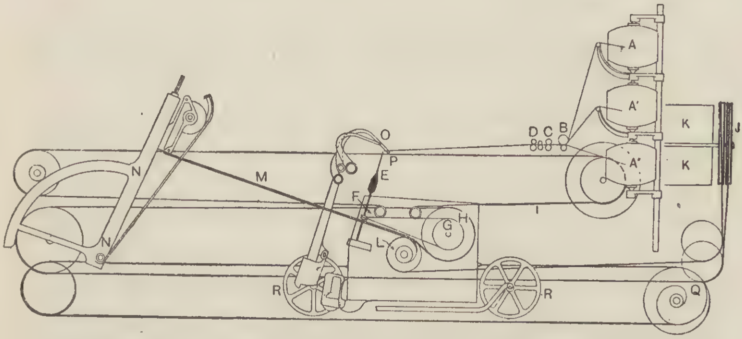


FIG. 17B.—Worsted Mule Section.—A, A_1, A_2, French drawn rovings ready for spinning; B, jack drafting rollers; C, carriers; D, front drafting rollers; E, spindle carrying spun yarn; F, wharl on spindle from which band passes to tin drum G; H, drum which conveys motion through the cord I, from the twist pulley J, in the headstock K, to tin drum G; L, a catch scroll which receiving a variable motion from the quadrant NN, through the chain M, gives the spindles the correct rotation to wind up the yarn for building a firm cop during the running in of the carriage at the same time that the faller wire O and counter-faller wire P direct and tension the winding up of the yarn, this being further controlled by the action of the "copping plate," which controls the up and down movement of the faller wires.

the exact turns per inch required may be inserted at double speed, and by a change of "copping-plate" the yarn may be spun on bobbins instead of on paper tubes.

From this description the two main features of mule-spinning, viz., the spindle-draft (properly spoken of as twisting-draft), and the twisting of unsupported threads will be fully realized. It should be noted, however, that as

previously remarked the machine just described should not be called a mule, for Crompton's "mule" received its name from being a hybrid combination of roller and spindle-drafting, while in the Woollen mule there never has been any roller-draft; it is simply an automatic jenny in the "billy" form.[1] The cotton and worsted mules, however, are genuine mules, as roller-draft in these plays almost a leading part. If, as very often happens, little or no spindle-draft is inserted by these mules the only possible advantage would appear to be in the method of inserting the twist. Against this presumable advantage there is the intermittent character of the cycle of spinning operations and the additional floor space occupied to be placed. That there must be an advantage is evident from the fact that mule spinning in the cotton trade at least holds its own, while in the case of the worsted it is rapidly making headway. In both these cases it may be that it is the peculiar method of sliver preparation, which it makes possible, which is the real advantage. This will claim attention in the next chapter.

It will have been noticed that although cotton is short fibred, nevertheless it is frequently spun on the roller-draft or long-fibre spinning method. This is accounted for by the nature of the cotton fibre, which is much more docile than wool and does not require length to control it, but may readily be controlled by the small drafting-rollers. In this connection it is interesting to note that prior to the mechanical era cotton yarns were probably spun very

[1] It is an interesting problem in economy of power to decide whether the spun yarn should be run backwards or forwards and the condensed sliver left stationary or *vice versâ*. Both forms are still in use to-day.

largely, if not entirely, upon the short-fibre spinning system. This is borne out by a knowledge of the cotton industry in India, in which the flax wheel plays no part, all the spinning being done on the simple spindle wheel. This rendered cotton spinning a relatively difficult process as compared with either linen or long wool spinning; hence the comparatively small number of people engaged in the industry prior to the mechanical era. But the introduction of the various automatic drawing and spinning machines rendered possible the drawing and spinning of cotton on the long-fibre principle; in fact it is practically true to say that the cotton industry is a machine-created industry. It would probably always have remained small but for the introduction of mechanical methods. It would also be interesting to investigate to what extent the short or Botany wool industry is a machine-created industry. It is true that woollen yarns were spun from short wools prior to the mechanical era, but the short wool worsted yarn is evidently a creation of the mechanical era; and consequently to this mechanical development must the large demand for Botany wools be attributed. That this is so is proved by the fact that the largest increases in the production of these yarns have taken place since the perfecting of the necessary preparatory machinery and the machine wool comb specially adapted for short wool combing, *i.e.*, between 1840 and 1880, although short Botany wools were previously largely employed in the clothing and woollen trade.

During the past twenty-five or thirty years many endeavours have been made to produce a frame yielding yarn possessing the same characteristics as yarn spun upon the mule. If such a frame could be produced a great

saving in space and a markedly increased output would be effected, since such a frame would be a continuous spinner, whereas the mule is an intermittent spinner. The difficulties to be faced are principally these:—Firstly, the continuous drafting of the sliver along with the insertion of the necessary drafting-twist; secondly, the insertion of the true thread twist; thirdly, the construction of a frame as easy to follow—to piecen up broken ends on—as the mule; and fourthly, a frame as inexpensive in both initial cost and in following as the mule. One of the first attempts was that made by Celestin Martin, of Verviers, in which a "twizzler" to insert false drafting-twist is placed between two pairs of drafting rollers, and a ring-frame arrangement placed to receive, twist and form a cop of the drafted but twistless yarn as delivered by the second pair of rollers. This machine, although employed to a considerable extent on the Continent, cannot be considered entirely satisfactory. The drafting being effected or supported by false twist is very different in character from that obtaining on the mule. Again, the vibration which runs along the thread in mule spinning owing to the thickness and inclination of the spindles is not attempted here. Again, the final twisting conditions obtaining on the mule do not in the least obtain here; and finally, the difficulties of piecening up are greater.

In Fig. 18 the latest style of mule-frame is shown. In this it will be noted that the "twizzle" (*B*) is placed practically upright and has two projections upon it. This is to give the "vibration" or short pulls to the thread which no doubt plays such an important part in spindle-drafting on the mule. This form of twizzle, however, obviously

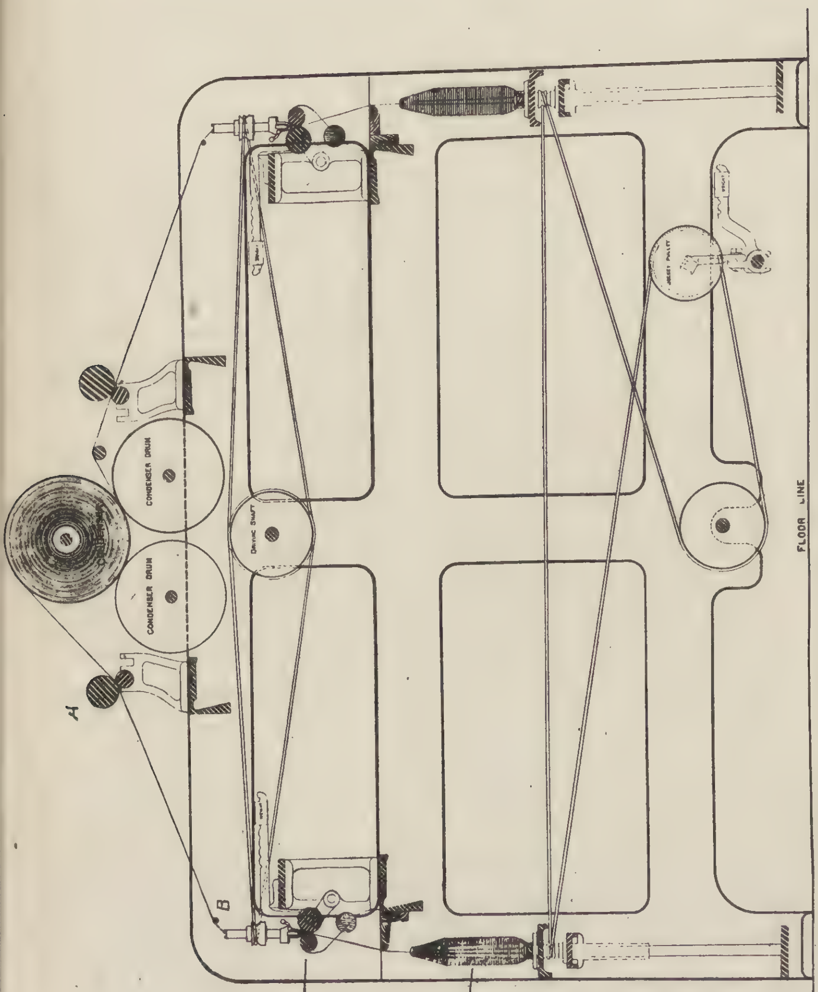


FIG. 18.—Platt's Mule-frame Sectional View. *A*, first drafting rollers; *B*, lugged twister; *C*, second drafting rollers; *D*, ring spinning frame.

increases the difficulties of piecening up. Arrangements are also made in this machine to make the drafting intermittent, but the twisting and winding on to the bobbin are continuous. As the main point in production lies in the twisting, this appears to be a move in the right direction. The conditions of final twisting, however, are the same as in the Celestin Martin's frame, and will probably result in a different yarn being produced as compared with the genuine mule-spun yarn. Considering the economic effect in the space occupied and the possibly greater production owing to the continuous action of the frame, it seems probable that this frame may be wisely and economically employed for the spinning of certain classes of woollen yarns, although its initial cost per spindle will probably be much greater than the mule.

In another frame of a similar style bars are inserted between the back and front rollers, near to the back rollers, with the idea of limiting the "run-up" of the twist in the thread, so that drafting may be more readily effected. This, however, shows a total want of perception as to the fundamental principles of spindle-draft.

Again the difficulty was supposed to be solved by the addition of an apparatus to the condenser, which took the slivers directly from the ring doffer—thus obtaining a "free-end"—and twisted them into what were called threads. As there was no draft at all in this case the resultant strands were simply twisted slivers and not spun threads.

From these attempts it would appear that for the spinning of characteristic woollen yarns—especially fine yarns with much twist—the woollen mule is not at all likely to be superseded.

CHAPTER VI

PROCESSES PREPARATORY TO SPINNING

In the foregoing chapter the various principles of spinning have been fully considered on the supposition that both long and short fibres of various classes were available for spinning. No account, however, was taken of the fact that in no case, with the partial exception of silk, are either the long or short fibres of commerce found naturally in a condition suitable for being spun into yarn. In fact, the variation in length in most materials necessitates a combing operation to classify the fibres which may be satisfactorily spun together, long spinning well with long, and short with short, but not long with short. Again, all contain either impurities natural to their growth or accidental impurities which get into the mass of fibres and must be removed before spinning can be attempted. In the first class the cortical substance in flax, the gums in China-grass, the yolk in wool, the gum in silk and the seeds in cotton, may be cited. In the second class water, beyond a certain amount, in flax, wool, and cotton; and burrs, seeds, straw, and sand in wool may be cited. Whatever the impurity be, it is usually necessary to remove it with the least possible damage to the fibre and to leave the fibre in a condition for being spun into a good useful yarn as already defined.

The processes preparatory to spinning are very varied, naturally being suited to each particular fibre. The principles involved, however, are all comprised in the following machines,[1] the action of which will be described after the natural requirements of the various fibres have been considered.

Machine.	Materials for which Employed.
The Gin	For cotton.
The Washing or Scouring Machine . . .	Wools and hairs.
The Dryer . . .	Wools, hairs, etc.
The Scutcher . . .	(*a*) For cotton. (*b*) For flax.
The Backwasher . .	Worsted slivers and tops.
The Gill-box . . .	Long wools and silk (modified form).
The Carder . . .	Medium and short wools and cotton.
The Dresser . . .	Waste silk and China-grass.
The Comb . . .	Wool, cotton, and sometimes silk and China-grass.
The Drawing-Box . .	Wool, cotton, and silk.
The Cone Drawing-Box .	Wool and cotton
The French Gill or Drawing-Box . .	Short wools.

The important points to study about these machines are, firstly, the principle underlying their construction; secondly, the way the material should be prepared for presentation to these machines; and, thirdly, the way in

[1] Net Silk Machining is treated separately in Chapter XV.

which these machines should deliver the material ready for the ensuing process or processes. Before dealing with these points, however, the natural requirements of each fibre should be considered, as it must always be the fibre which decides the type of preparing machine—even iron and steel must conform to soft cotton and wool, lustrous silk and harsh China-grass. Thus in the preparation of cotton and wool for spinning on the short-fibre principle good carding is so important that the resultant spin may absolutely be said to depend upon it. In the preparation of flax and certain other vegetable fibres for spinning on the long-fibre principle satisfactory retting, scutching and dressing are equally important. In the preparation of long animal fibres such as English wool, mohair, and alpaca, as also in the case of the "combed" cottons, an averaging of the fibres by means of the operation of combing—which in turn has its preparatory processes in the form of carding or preparing—is necessary to ensure a satisfactory spin. It is obviously impossible to say that any one process is the most important in the sequence; each operation must be worked to the best advantage if good results are to be finally attained.

Four Methods of Preparing Vegetable Fibres for Spinning.—To ensure satisfactory results in the spinning it has been found necessary to employ at least four distinct methods of preparation for the various types of vegetable fibres, each of these methods having been naturally evolved through experience with the respective fibres to which each is best suited. These four methods are as follows:—

1. *Air-blast Preparation.*[1]—This is chiefly employed for

[1] See p. 128 for description of ginning machine, the first machine employed in cotton.

cottons, being the main principle of the openers, scutchers, and perhaps not altogether inactive in the carders. The initial stages of the preparation are usually followed by carding, sometimes combing (as explained in the chapter on the Cotton Industry), and then drawing as directly preparatory to spinning.

2. *Retting Preparation.*—This is chiefly employed for flax and a few analogous fibres, in which the fermentation due to steeping in peaty water, or perhaps "dew retting," is sufficient to destroy the cortical substance in the flax stems and thus render fairly free the fibrous portion. Scutching to further loosen any cortical particles still adhering, and dressing, complete the cleaning preparation of the fibres, which are then got into sliver form, as in the case of long wools, etc., and finally drawn and spun on the long-fibre principle as already explained.

3. *Scraping Preparation.*—This method is employed for such fibres as Ramie and China-grass, in which no form of retting is altogether satisfactory, probably owing to the gums which act as firm binding or integrating agents. Not only is a good scraping in running water usually necessary, but "degumming" by means of caustic soda or other reagents is also necessary later. Once the "filasse" is in a really fibrous and clean state it may be treated somewhat on the flax principle, or, better still, on what is known as the "spun silk principle," in which an averaging up of the fibres is effected by a process known as "dressing" (see p. 126) followed by sliver forming arrangements similar to those employed for long wool, and spinning on the long fibre principle.

The Noble comb is sometimes employed in place of the dressing frame, but is not nearly so effective.

4. *Artificial Preparation.*—As artificial silk spinning is here in question and as most artificial silks are formed from vegetable matter, such processes should claim consideration here. The spinning referred to is not really spinning, it is rather a drawing-out of a prepared wood or cotton pulp into a fine filament which, hardening on exposure to the air or by special treatment, thus becomes a fine strand and is later twisted or "thrown" with other strands to form in turn a true thread. As the later principles involved are those of silk throwing no further description is here called for. It is interesting to note, however, that artificial flax is now being placed on the market, and no doubt other varieties of such fibres or filaments will follow.

Four Methods of Preparing Animal Fibres for Spinning.—As animal fibres are usually delivered into the hands of the spinner in a fibrous state, their preparation is different from that of flax, etc.; on the one hand by reason of the absence of the necessity for mechanical treatment, and on the other hand in that certain adhering impurities must be removed by certain chemical or chemico-physical operations, the washing or scouring of the wool, etc., being the chief of these. This operation of scouring, however—take what care one will—frequently so mats the wool or hair that special machines must be employed to disentangle it and constitute it into a sliver suitable for spinning from on the short-fibre principle or a sliver suitable for spinning from on the long-fibre principle.

The four methods of preparation employed for wool and hairs are as follows :—

1. *The Woollen Method.*—In this case willowing, teasing, scribbling, and carding result in the wool being delivered as a broad continuous film—with fibres perfectly dis-

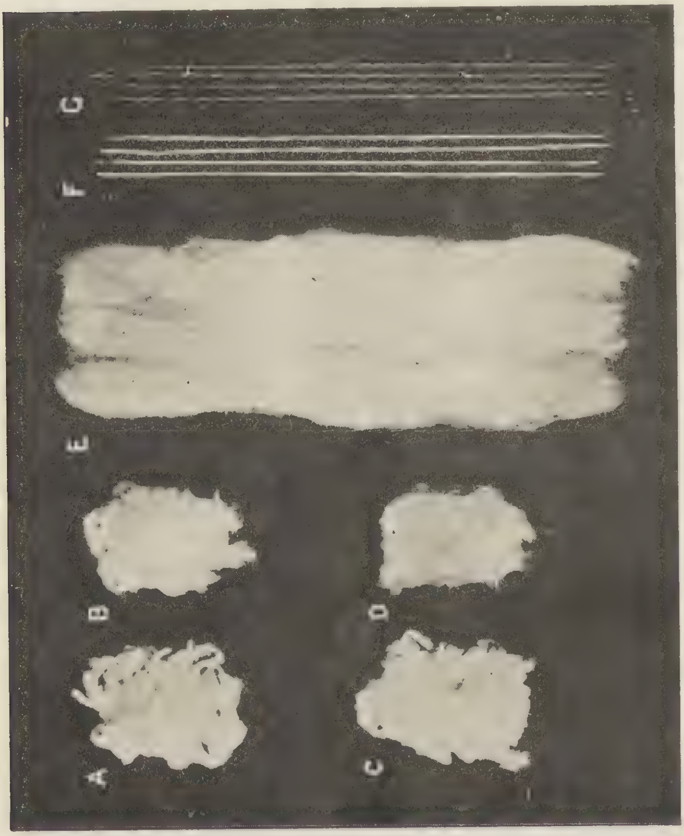


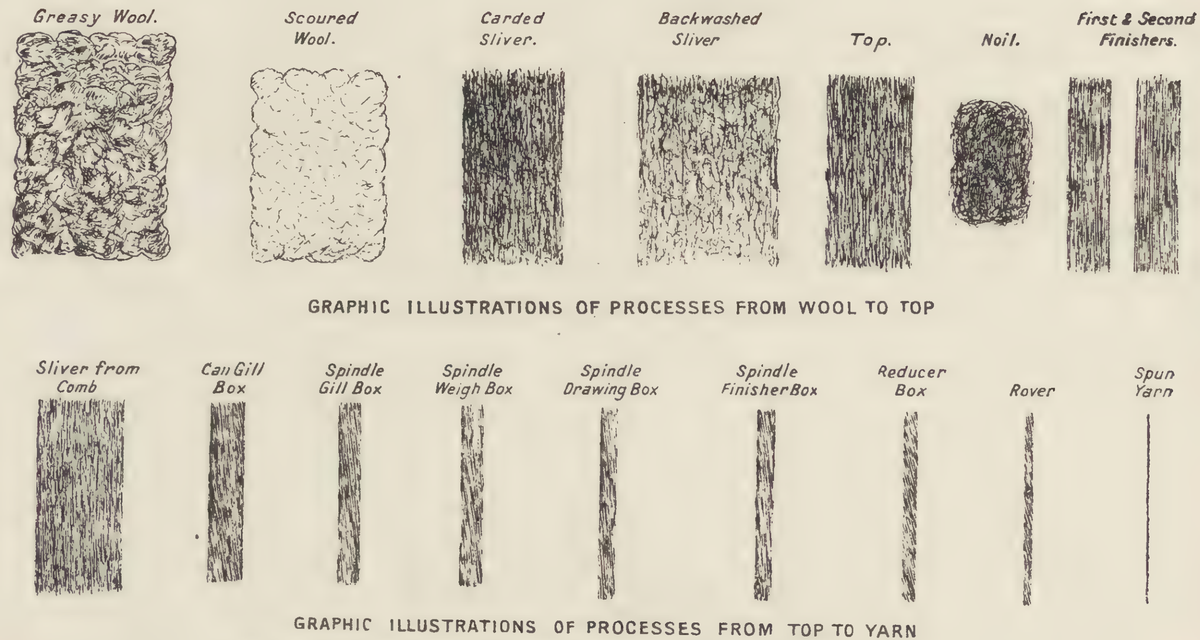
FIG. 19.—Stages in Woollen Yarn Spinning. *A*, wool to be blended with cotton *B*; *C*, blend of oiled wool from Fernaught; *D*, blend from scribbler; *E*, blend in rope form from intermediate card; *F*, condensed slivers; *G*, mule-spun thread.

tributed—to the condenser which breaks the broad film of, say, 48 to 72 inches up into 60 to 120 pith-like filaments—not threads, as there is no twist in them—which

are continuously wound on to the condenser bobbins, which in turn are transferred to the mule to be spun into threads by additional draft and twist. (See Fig. 19.)

2. *The Botany Worsted Method.*—Fine, fairly short wools which later may be spun on the long-fibre principle are carded to obtain an even distribution of the fibres in the sliver delivered from the card. But the carding operation no doubt tends in part to arrange the fibres longitudinally in the sliver, being aided in this by the way in which the sliver is drawn off the machine as compared with the delivery of the sliver from a woollen card. The combing operation now follows, being undertaken with the idea of taking away the short fibres, termed "noil," and thus leaving in the slivers to be spun only the fibres of a good average length. Gill-boxes and drawing-boxes then effect the "straightening" necessary before spinning can be satisfactorily undertaken, the two principles of "doublings" and "draft" being applied with the idea of obtaining a level sliver which will spin out to the required count. The excess of draft over doublings gives the reduction in thickness of sliver. The knowing when to double and when to draft to obtain level slivers is still only imperfectly understood. (See Figs. 20 and 20A.)

3. *The English Worsted Method.*—Long wools and hairs such as mohair, alpaca, etc., are treated on this system, although it is well to note that there is a marked tendency to prepare by carding much longer wools than was formerly the case. These long-fibred materials are gilled as a preparation for combing and combed on the Lister or Noble comb. Gill-boxes and drawing-boxes then effect the necessary "straightening" prior to spinning, doubling and



FIGS. 20 and 20A.—Stages in Wool Combing and Worsted Yarn Spinning.

drafting being applied very much as in the case of Botany wools, but as a rule there are fewer operations.

4. *The French Worsted Method.*—The shortest and finest Botany wools are prepared for spinning on this method, the principle being that the wool is treated in an open condition without twist by drafting rollers throughout, twist being unnecessary. Of course special support and

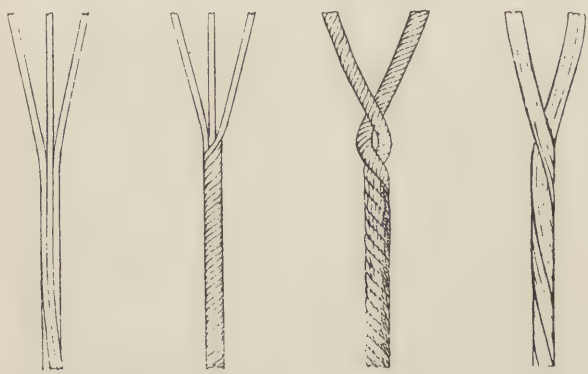


FIG. 21.—Graphic Illustration of Net Silk Yarns.

control of the wool during drafting and a special form of delivery are necessary. The worsted mule almost invariably forms the climax to this method, although there is a question as to whether spinning on the cap principle may not yield economical and useful results.

Two Methods of Silk Preparation.—The special characteristics of silk are its gumminess and its "slipperiness." These two factors play an important part in deciding the processes through which the fibre shall pass. The two

great methods of preparation are designed for the "net" silks and the "waste" silks respectively, the "net" silks requiring a "continuous fibre process" and the waste silks simply a "long-fibre process."

1. *The Continuous Fibre Silk Process.*—In this case the

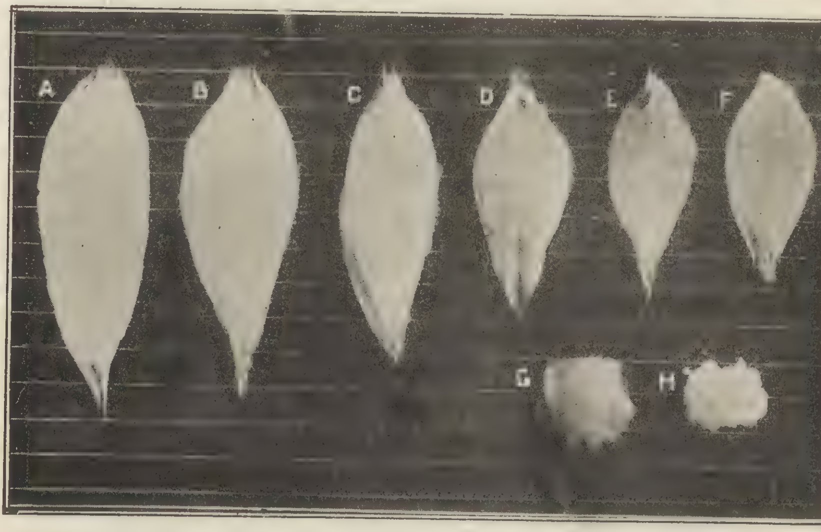


FIG. 22.—Spun Silk Drafts (the horizontal divisions = 1 inch). *A*, *B*, *C*, *D*, *E*, and *F* are 1st, 2nd, 3rd, 4th, 5th, and 6th drafts; *G*, the shorts, and *H* the noil.

fibre is simply reeled from the cocoon its full length, cleaned, softened, and "thrown" with other fibres, twist being inserted according to requirements, quantity and direction being important matters to attend to (see Fig. 21). In this case the preparation for the spinning or "throwing" is very similar to the actual throwing operation. Degumming is effected with soap and hot water, and may

be carried out either after spinning or advantageously after weaving, as the silk gum strengthens the thread and results in better work right away through the processes. The

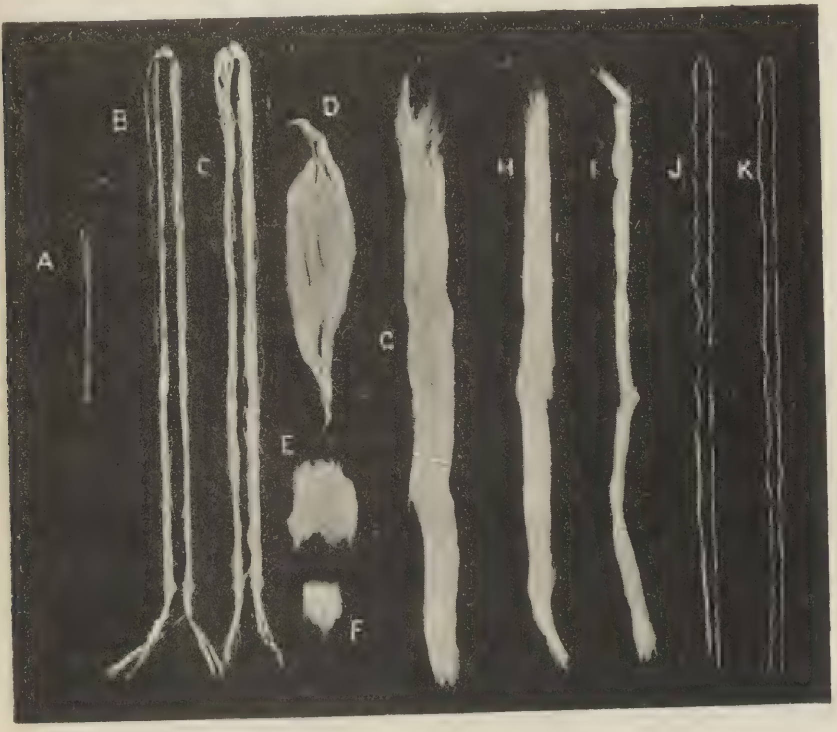


FIG. 22A.—Stages in China Grass Spinning. *A*, stem of Bœhmeria Tenacissima; *B*, decorticated fibrous mass; *C*, degummed and bleached filasse; *D*, dressed filasse; *E*, shorts; *F*, noil; *G*, sliver from spreader; *H* and *I*, slivers from intermediate boxes; *J*, the roving; and *K* the spun thread.

necessity for dyeing and the difficulty of degumming certain fabrics result in large quantities of silk being woven in the degummed form.

2. *The Long-Fibre Silk Process.*—In this case the fibres, although long—say 8 inches to 12 inches—are not continuous. They may be prepared and got into fairly satisfactory sliver form by rollers and gills (which are usually of the intersecting type to control them better), but to spin them satisfactorily the fibres must be averaged up on the dressing-frame—*i.e.*, separated, say, into seven lots or "drafts," as they are termed, according to the length of fibre, the first draft being, say, 12 inches, the second 10 inches, and so on (see Fig. 22). The slippery nature of the silk fibre necessitates its treatment on the "dressing-frame"; in fact, this fibre has given rise to the dressing-frame, which now is not only employed for silk, but also very largely for China-grass (see Fig. 22A).

The still shorter or real waste silk may be again carded up and prepared and spun upon the Botany worsted method.

Typical Example of the Method of Preparing and Spinning a Textile Material (China-grass or Ramie).

Ramie Manufacture: Order of Processes.

1a. Decorticating usually on plantation while stems are green.
1. Boiling with caustic soda, etc.
2. Bleaching—ordinary method.
3. Washing.
4. Hydro-extracting.
5. Heat drying—without confusion of "fibre-bundles."
6. Roller-softening. Through rollers—6 inches forward, 3 inches backward, etc.

7. Carding and fibre cutting process. 18 combs. Cuts at $7\frac{3}{4}$ inches.
8. Dressing between 32 corks on flat dressing-frame with stripping drums.
9. Spreading or gilling (intersecting gills). Lap-drum 3 feet in diameter. Ratch=11 inches to 12 inches. Fallers occupy space of 8 inches. Two passages.
10. Gilling (ordinary). Ratch 11 inches to 12 inches. Fallers occupy space of 8 inches.
11. Drawing on open-gill—4 heads. Ratch 11 inches to 12 inches. Fallers occupy space of 8 inches.
12. Roving on 40 spindle frame. 1 sliver up. Ratch 10 inches to 11 inches. Fallers occupy space of $7\frac{1}{4}$ inches.
13. Doubling on 60 spindle frame. 2 to 4 slivers up. Carriers in place of gills.
14. Hot water spinning on 300 spindle ring frame. Ratch of 10 inches.
15. Dry twisting on 272 spindle ring frame.
16. Gassing on gassing frame.
17. Reeling.
18. Bundling.

PREPARATORY MACHINES

Each of the machines previously mentioned must now be briefly described, when the reader will no doubt be able to adjust the requirements of any particular fibre to the mechanical principles of any required machine, or *vice versâ.*

The Cotton Gin.—This machine in its simplest form consists of a roller with a broad steel blade sprung against it. The roller draws the cotton round between itself and the blade, and the seeds, being large and hard, instead of following are freed from the cotton fibre and drop off into a receptacle arranged for them (Figs. 23 and 23A).

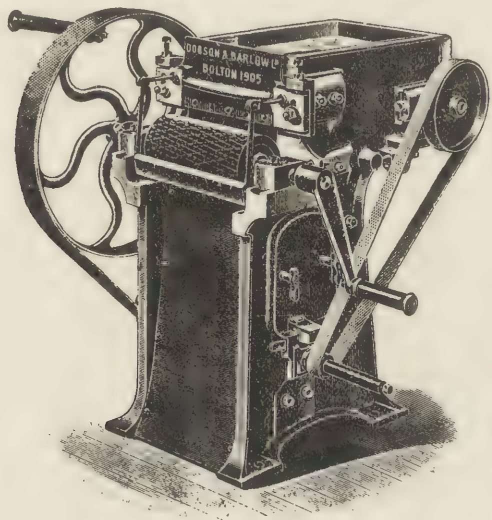


FIG. 23.—Cotton Gin.

The Washing or Scouring Machine.—This primarily consists of a bowl for holding the heated scouring liquor in which the wool is to be cleansed by immersion. This appears very simple, but a few moments' thought will show that some complexity is inevitable. The liquor must be maintained at a definite heat, hence steam must be laid on; it will also be advisable to lay on water, soap liquor and

possibly alkali, so that perfect control of the temperature, heat, and strength of the liquor is obtained.

The yolk, sand, dirt, etc., got out of the wool must be disposed of. Thus, satisfactory means of emptying the bowls must be adopted, drain pipes being suitably fixed to the bowl or bowls to deliver the liquor to the settling or waste product tanks.

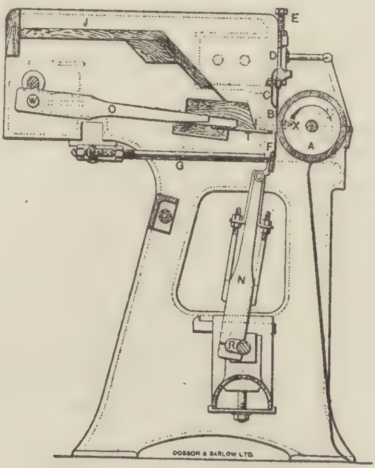


FIG. 23A.—Section of Single Macarthy Cotton Gin.

But, again, during the operation of scouring the dirt and grease, etc., should be got away from the wool entering the bowl, this being usually effected by the settling which takes place by floating the liquor out with the wool and arranging for a tank at the side for the grease, sand, dirt, etc., to settle into, but so constructed that it may be readily cleaned out.

The propelling of the wool from one end of the tank to the other and especially taking it out of the machine

are also matters which require very careful thought and arrangement.

Scouring sets now frequently consist of four or five machines giving about 60 to 80 feet of bowl, in which the wool is immersed on an average for about eight minutes.

It may be interesting here to give a brief *résumé* of the evolution through which wool scouring has passed.

The first idea was to pass the wool rapidly through the scouring liquor; this matted the wool, prevented perfect scouring, and resulted in bad work throughout all subsequent processes.

Then the idea of forcing the scouring liquor through the wool was tried, with a very similar result.

Then it was realized that the natural tendency of wool to open out when placed in water—when the surface tension was removed—must be made the basis of wool scouring, and the wool was floated along with the scouring liquor.

Then the idea of a wet nip or "possers" was tried and found wanting, a wet nip apparently nipping dirt into the wool.

Finally it was realized that a combination of circumstances and conditions was necessary, that attention must be paid to all points, and the bearing of one point upon another fully taken account of. Thus were evolved the sets of modern wool-scouring machines in which the necessary agitation may be obtained, but which deliver the wool free, clean and wonderfully dry.

Modifications of wool-scouring machines to effect "wool steeping," and thereby reclaim the valuable potash salts, are also placed upon the market.

The Dryer.—There are several forms of drying machine,

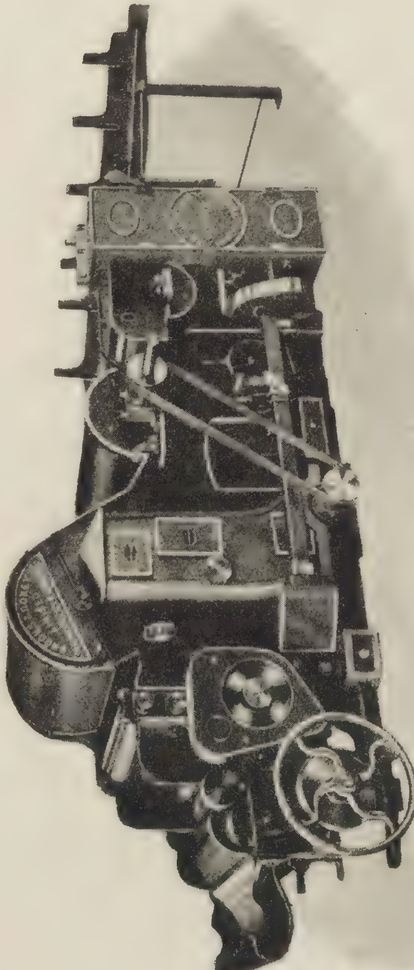


FIG. 24.—The Cotton Scutcher.

such being necessary in the case of English and cross-bred wools after scouring and also useful in such operations as carbonizing. The drying machine has followed an evolution similar to the scouring machine. The material to be dried has been held and air forced through it—as in the case of the table dryer; the material to be dried has been carried into the drying air, and last, and perhaps best of all, the mean between the two has been adopted as in the latest form of McNaught dryer.

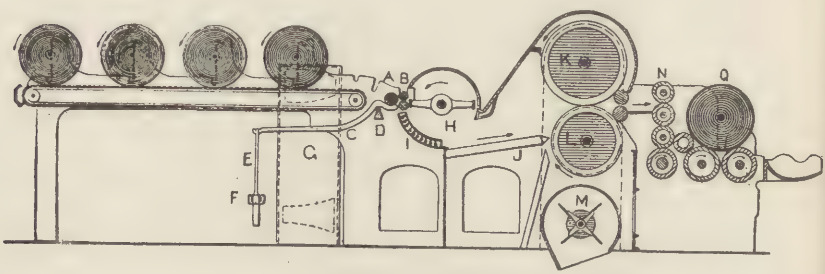


FIG. 24A.—Section of Single Cotton Scutcher.

The Cotton Scutcher.—This is a machine to thoroughly disintegrate and clean the cotton prior to carding. Briefly it consists of "cage" rollers upon which the cotton is blown, which pass it forward until eventually it is delivered as a lap. Suitably arranged "grids" allow sand and heavy foreign matters to drop out of the air currents; thus the cotton is fairly well cleaned and freed prior to carding (Figs. 24 and 24A).

The Flax Scutcher.—This is a machine to beat and break the flax straw after retting so that it is in a suitable state for the dressing frame. It is practically a "breaker" of the flax straw and also a partial cleanser (Fig. 25).

The Backwasher.—This machine usually consists of two small washing or scouring tanks, drying cylinders, and

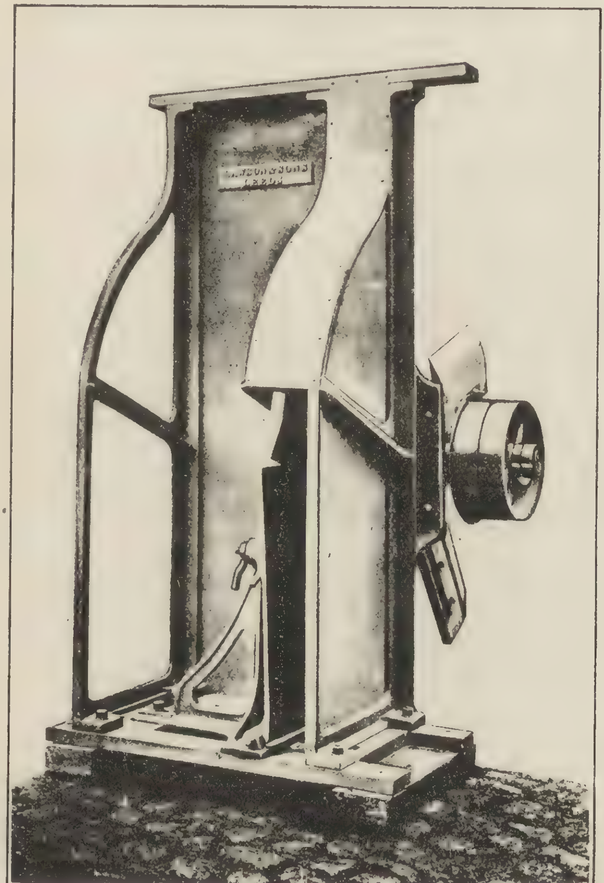


FIG. 25.—The Flax Scutcher.

a straightening gill-box. It is made in several forms, for each type certain constructional advantages or advantages

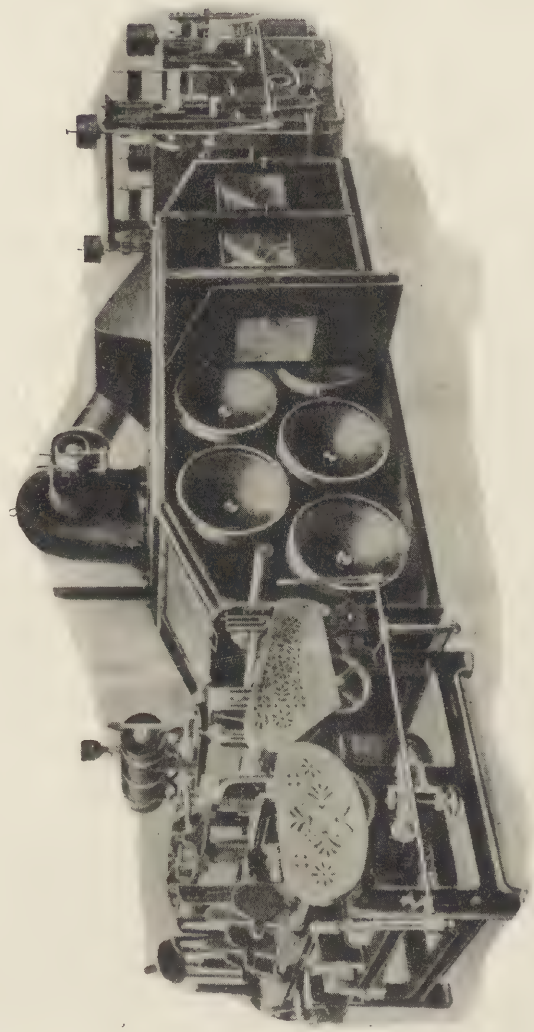


FIG. 26.—The Backwasher with Hot-air Drying.

for the material treated being claimed. It is employed either before (in England) or after (in France) combing to thoroughly clean worsted slivers or "tops," for not only does the wool become sullied in passing through the several preparing machines, but impurities which cannot be extracted in the scouring bowls have revealed themselves and may here be conveniently got rid of. The process of "blueing" to give a white appearance to the slivers or tops is frequently resorted to, and is usually effected on the backwasher. The latest innovation in this machine is the adoption of hot air drying in place of cylinder drying (see Fig. 26).

The Preparing Gill-box.—This consists of a pair of back rollers, gills or fallers riding on screws, and front rollers, with feed sheet and lap, balling-head or can delivery. The action on the wool may be either a combing action or principally a drawing action. For example, when wool is much matted the fallers, working quicker than the back rollers, comb out the fibres and deliver them to the front rollers, which should be set to the fallers. But when the material has been much worked and is fairly straight, the faller-pins simply slip through the fibres and consequently can only act as supports between back and front rollers; in other words, the operation becomes largely a drawing operation.

As pointed out with reference to cotton, the distance apart of drawing rollers, size of rollers, etc., must be very carefully considered. With wool the ratch or distance between back rollers and fallers or back rollers and front rollers is equally important, but as the wool fibre is so much larger than the cotton fibre the size of the rollers need only be

taken into account from a wear and tear and possibly from the grip and weighting points of view.

The Preparing Gill-box may be best considered as an

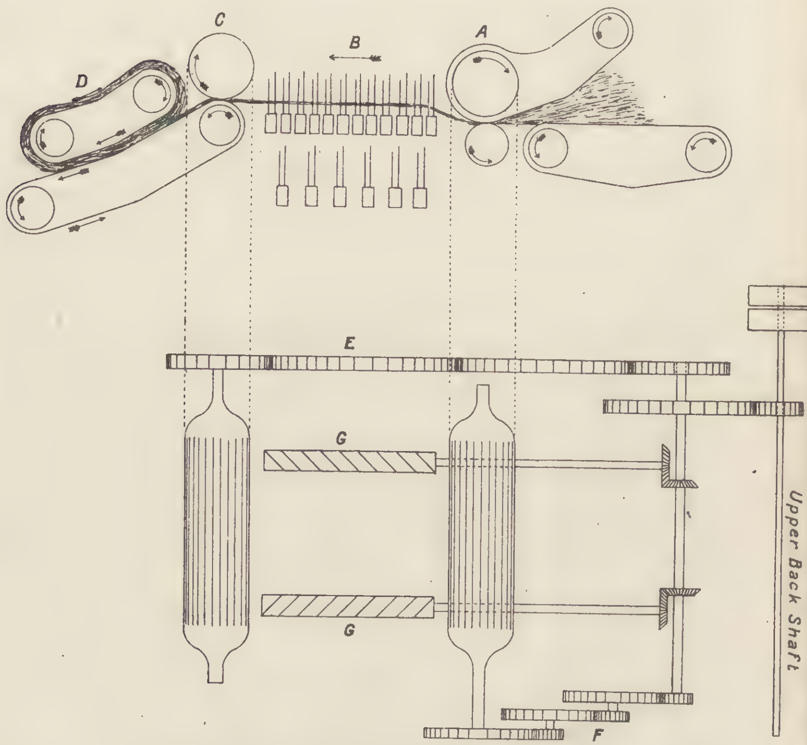


Fig. 27.—Plan and Elevation of Sheeter Gill-box. *A*, back rollers; *B*, fallers set with pins (gills); *C*, front rollers; *D*, sheeting leathers; *E*, train of wheels driving front rollers; *F*, train of wheels driving back rollers; *G*, screws driving the fallers or gills.

admirable straightener for wool and the various long animal fibres, and also as a mixer for fibres of varying qualities or colours (see Figs. 27 and 27a).

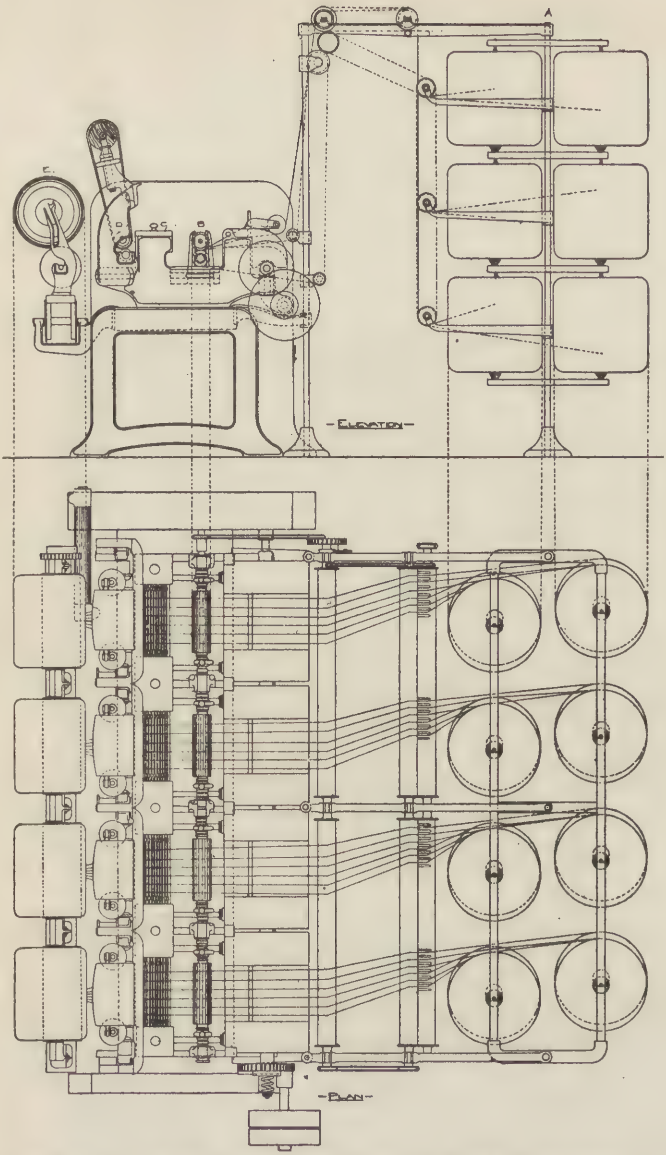


FIG. 27A.—Four-head French Gill-box in Plan and Elevation. *A*, creel; *B*, back drafting rollers; *C*, pinned fallers or gills; *D*, front drafting rollers; *E*, balling head.

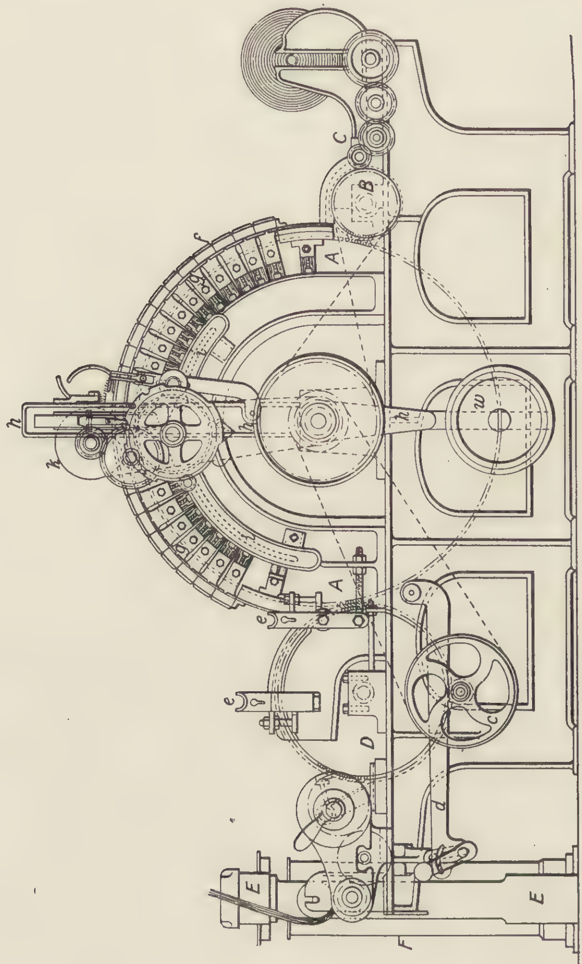


FIG. 28.—Self-cleaning Flat Cotton Carder, illustrating the Evolution from the Early Form of Card to the Revolving Flat Card.

The Carder.—This machine has been evolved from the hand-cards, such as are still used in the home industries of Scotland and Ireland. The first step towards an auto-

matic card was made when a cylinder—which might be turned by hand—was clothed with card-clothing and the wool worked between this cylinder and a flat card held in the hand. This early form of card gave rise to the flat and the revolving flat cards still largely employed in the cotton trade. Finally the whole of the carding was effected by cards mounted upon cylinders, and after many trials, involving both successes and failures, the modern roller card was evolved. It is here interesting to note that, owing to the susceptibility of cotton to air blasts, the cotton roller card is invariably made narrow and enclosed more than is the wool card; while, as a matter of fact, probably due to this, and also to the fibre length, the flat card seems the favourite for cotton (see Fig. 28).

In working carding machinery there are two main points to be attended to, viz., the satisfactory carding of the material and the designing and arrangements of the various parts to work to the greatest advantage with the least possible wear and tear. The satisfactory carding of the material depends in the first place upon the principle upon which the card works. This in the case of the roller card is as follows:—The swift acts as the main carrying cylinder constantly endeavouring to pass the wool forward, but is opposed by the teeth of the workers, which, acting as a sort of sieve, do not allow material to pass them until it is finely divided up. Thus from beginning to end of a card the workers should be set closer and closer—the first worker a fair way off, the last close to the wires of the swift, but never touching.[1] Thus material is really worked

[1] This is not quite true, as in carding mungo, etc., the wires are set to run into one another.

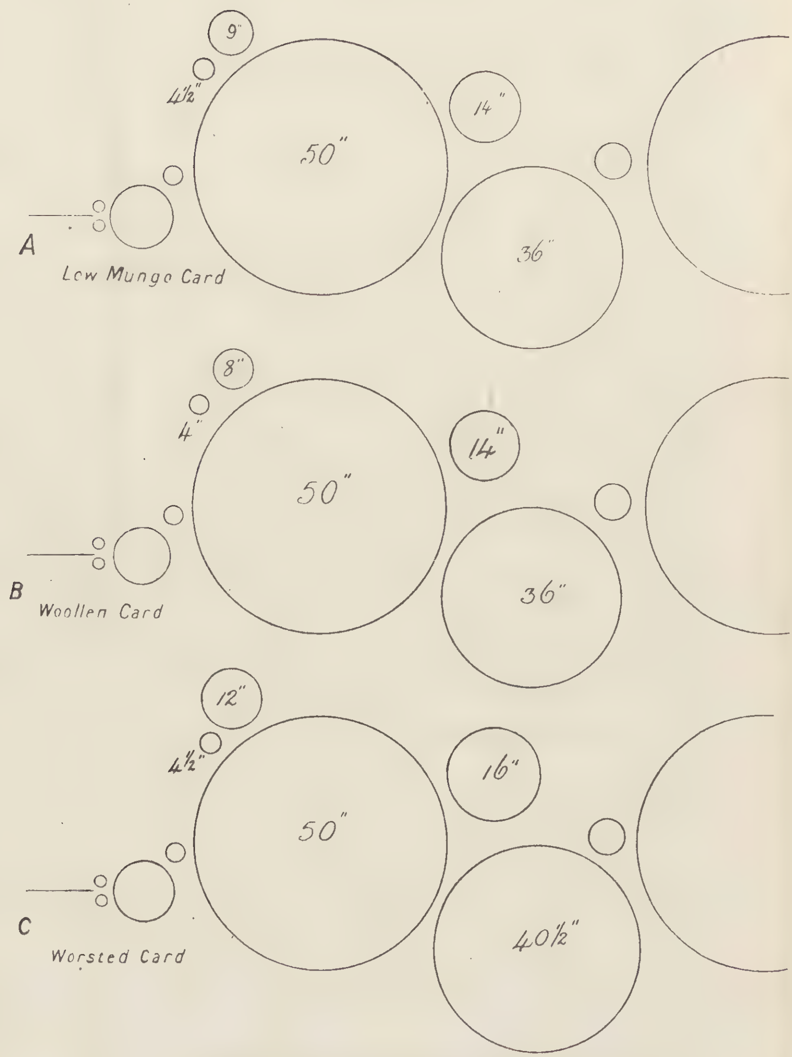


Fig. 29.—Illustrating the Sizes of Cylinders in Cards for Carding Various Qualities of Wool.

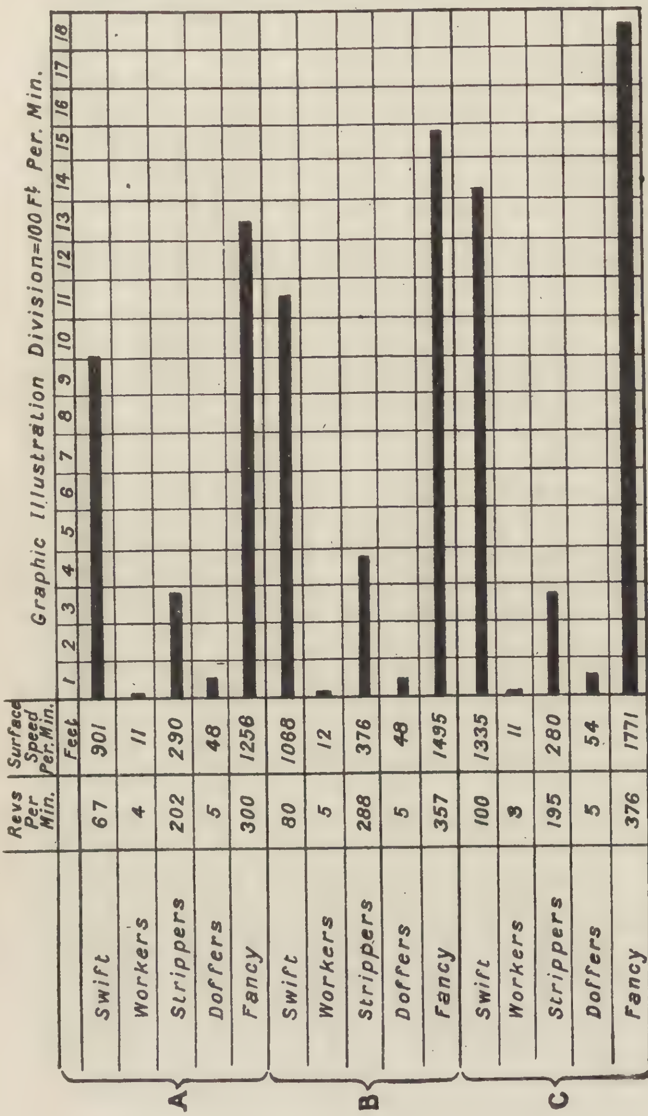


FIG. 30.—Graphic Illustration of the Surface of Speed of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

		Count	Crown	Teeth Per Sq. Inch
A	Swift	100	10	400
	Workers	105	10	420
	Strippers	90	9	324
	Doffers	110	10	440
	Fancy	65	7	182
B	Swift	130	11	572
	Workers	135	11	594
	Strippers	100	9	360
	Doffers	140	12	672
	Fancy	80	8	256
C	Swift	140	12	672
	Workers	145	12	696
	Strippers	110	9	396
	Doffers	150	13	780
	Fancy	80	8	256

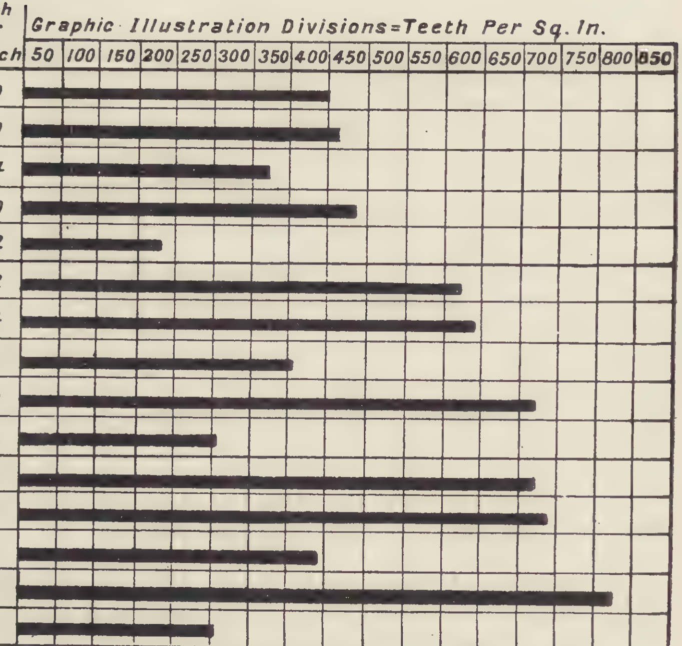


FIG. 31.—Graphic Illustration of the Wire Clothing of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

by material. The material is condensed or "doubled" on the workers and then elongated or drafted by the strippers, and again by the swift stripping from the strippers. This is the carding operation; feed-rollers, licker-in, fancy and doffer being the means of conducting wool into and out of the machine. It will be noticed that the satisfactory accomplishment of the operation just described depends upon (a) the surface speeds of the rollers, which in part necessarily influence the size of these rollers; (b) the direction in which the rollers revolve; (c) the inclination or bend of the card teeth; and (d) upon the relative density of the card-teeth with which the various rollers are clothed. The wear and tear upon a card depend largely upon the size of the rollers, and of course upon the practical setting.

The material of which the cards are built is of course another important matter, but ordinary engineering principles here apply. Iron is more stable than wood but is readily broken, while wood is more convenient but does not long remain "true." The following diagrams and lists will illustrate the principles of carding and of satisfactorily clothing the card cylinders (see Figs. 29, 30, and 31).

The Dresser.—This machine takes the place of the comb when the material is (a) too rough, as in the case of flax, to be satisfactorily combed; or (b) too slippery, as in the case of silk and china-grass, to be satisfactorily combed.

Briefly, it consists of a series of boards, books or holders between which one end of the material to be dressed is firmly clamped and held; a framework upon which these boards may be fixed so as to be carried continuously into the machine or placed in the machine and withdrawn when necessary; and a series of cleansing combs with

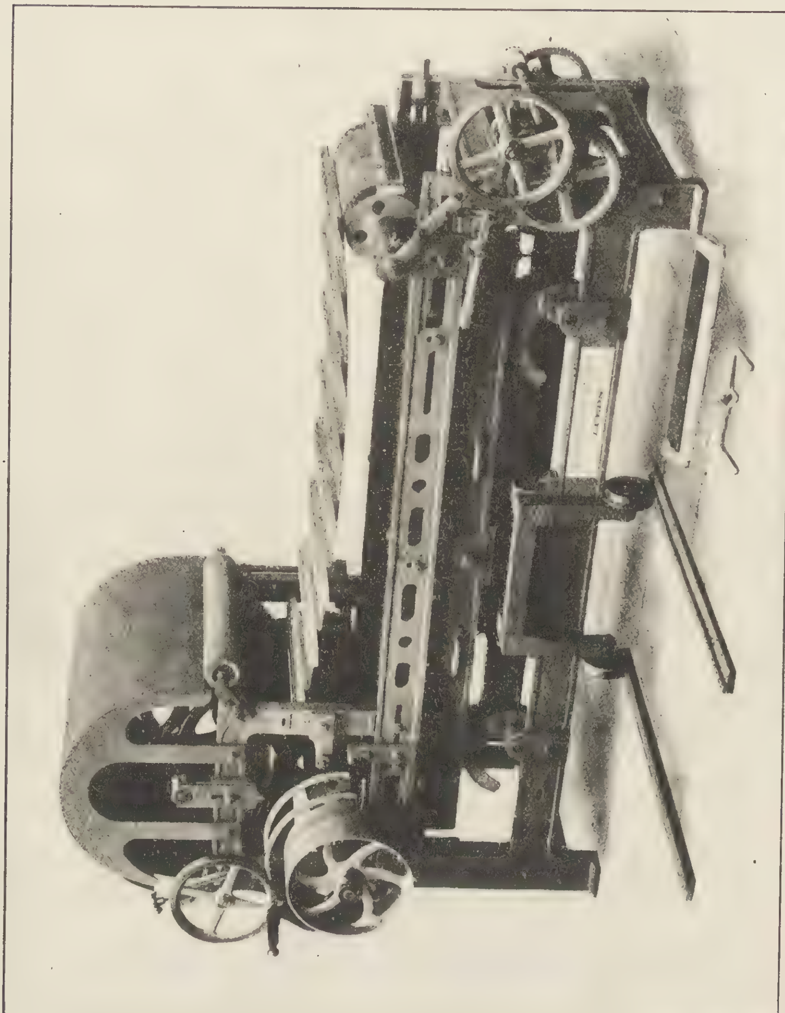


FIG. 32.—Silk Dressing Frame.

cleaning or noil arrangements so that they may work to the greatest advantage.

The material may be presented upwards to the combs as in the case of silk, or downwards as in the case of flax. In the case of silk-dressing the operation is undertaken more with the idea of averaging the fibres into the several different "drafts"; in the case of flax the operation partakes more of a cleansing character (see Fig. 32).

The Comb.—While combing may in part be said to be based upon the idea of averaging up the fibres, still more

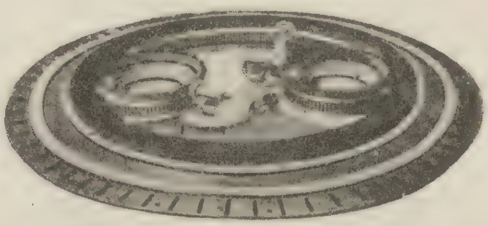


Fig. 33.—Position of Large and Two Small Circles in the Noble Comb.

truly may it be said to consist in combing out all fibres under a certain length, leaving the long or top wool to form what is termed the "top" and the short to form "noil." Along with combing, as with dressing, must go a straightening operation; in fact, in the days of the hand comb, the second combing was termed "straightening."

There are two types of comb in use, the horizontal circular and the vertical circular. The Noble comb is the best representation of the horizontal circular (Figs. 33 and 33A). The combing operation here is based upon the drawing out of the long fibres between the diverging circles until the one having the shortest end as it were leaves go, leaving the

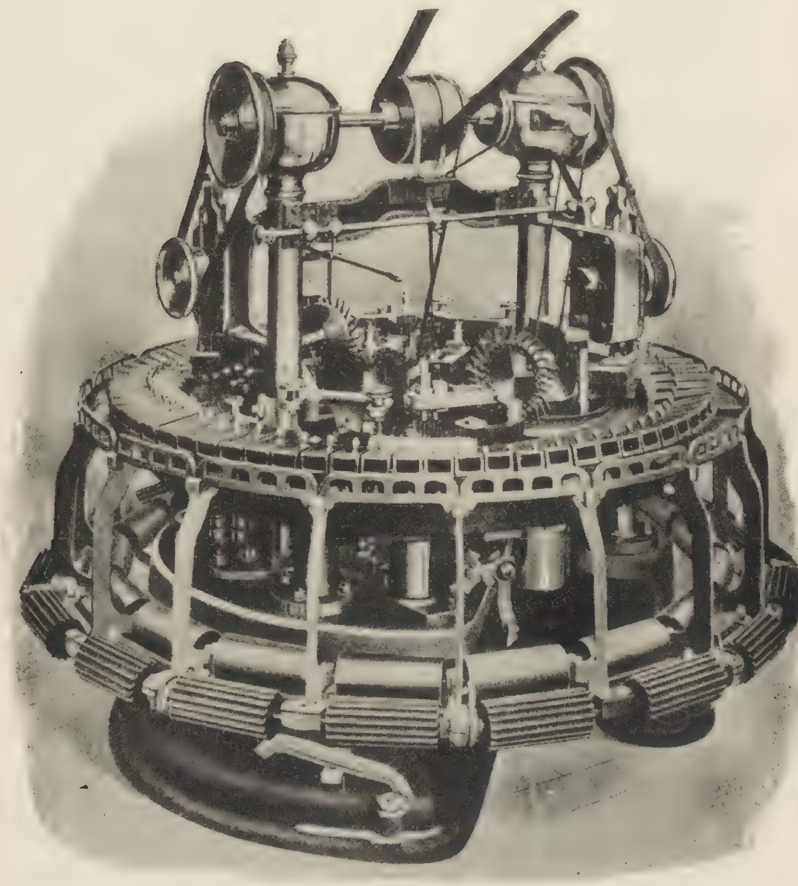


FIG. 33A.—Self-supporting Noble Comb, latest Form.

long fibres hanging on the outside of the small circle and the inside of the large circle, from which they are drawn off by suitably placed rollers. The noil in the meantime

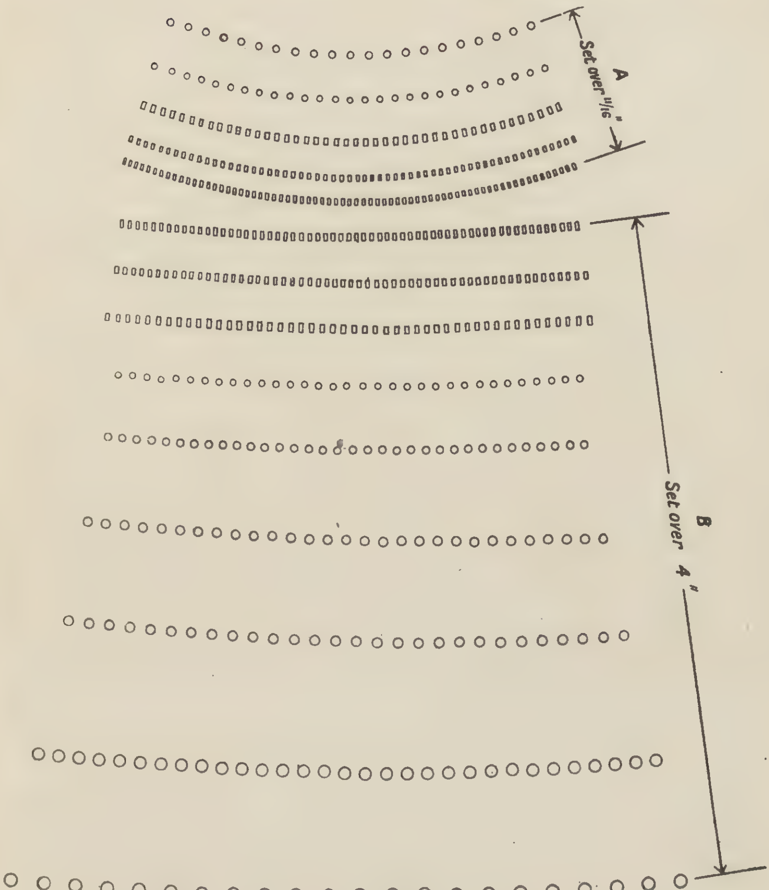


FIG. 34.—Pricking from a Long Wool Noble Comb Circle. *Note.*—For a Botany Comb the "set over" for *A* is $\frac{5}{8}''$, the "set over" for *B* is $1\frac{3}{4}''$.

has been held within the pins, and ultimately is taken off from between the pins of the small circles by what are known as noil knives. The pinning of Noble comb circles

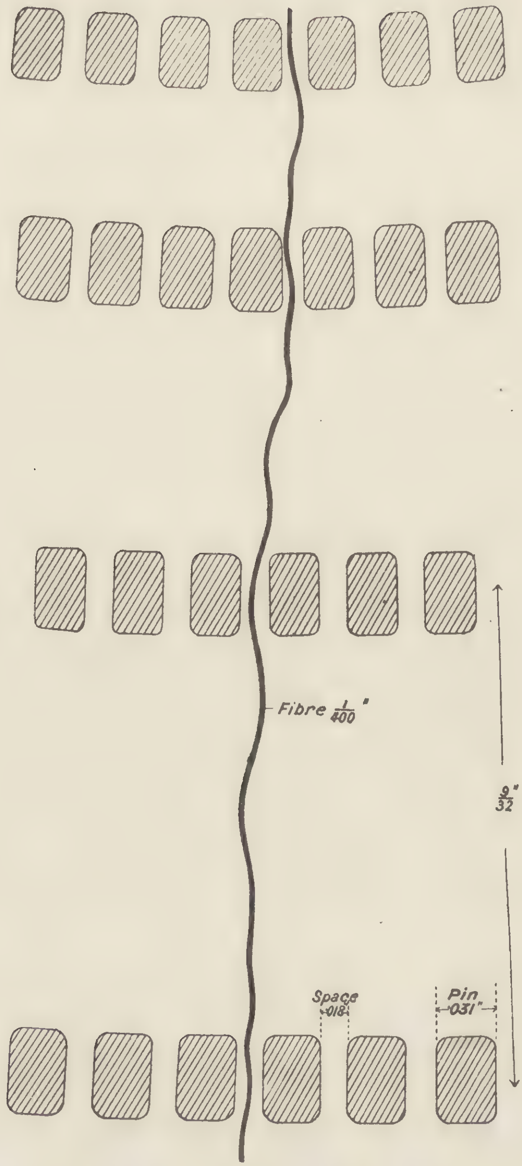


FIG. 34A.—View of Wool Fibre in the Pins of a Noble Comb. Drawn to scale.

should be definitely based upon the diameter of the pin and the space to leave in between for the fairly free running of the fibres—say, one-fourth pin to three-fourths space.

As the satisfactory holding of the fibres by the pins is the basis of the Noble comb, it will be realized that, not only must the distance apart and thickness of the pins be taken into account, but also the set-over or space over which the pins are set (see Figs. 34 and 34A).

The Heilman comb in its various forms is the best example of the vertical circular comb. Briefly, it consists of a pair of jaws to hold a tuft of fibres, a comb cylinder to comb one end of this tuft, a pair of rollers to take hold of the combed end, combs through which the uncombed end may be drawn and thus combed, and a continuous lap forming arrangement. As in most combs the operation of combing must be more or less gradual, the comb cylinder here employed has the first row of teeth fairly openly set, the next closer, and so on, the finest being set about 60 per inch for wool and about 80 for cotton. There is also a preparation of the sliver for combing prior to the jaws referred to coming into action.

The Drawing-box.—This is similar in many respects to the gill-box, but lacks the gills or fallers, their place being taken by carriers which support the wool between back and front rollers. The distance between back and front rollers is usually somewhat greater than the length of the longest fibre being treated, so that in part fibre may be said to be worked by fibre (see Fig. 35).

The Cone Drawing-box.—So far as the drawing action of this box is concerned the action is the same as in the ordinary box. As remarked, however, with reference to

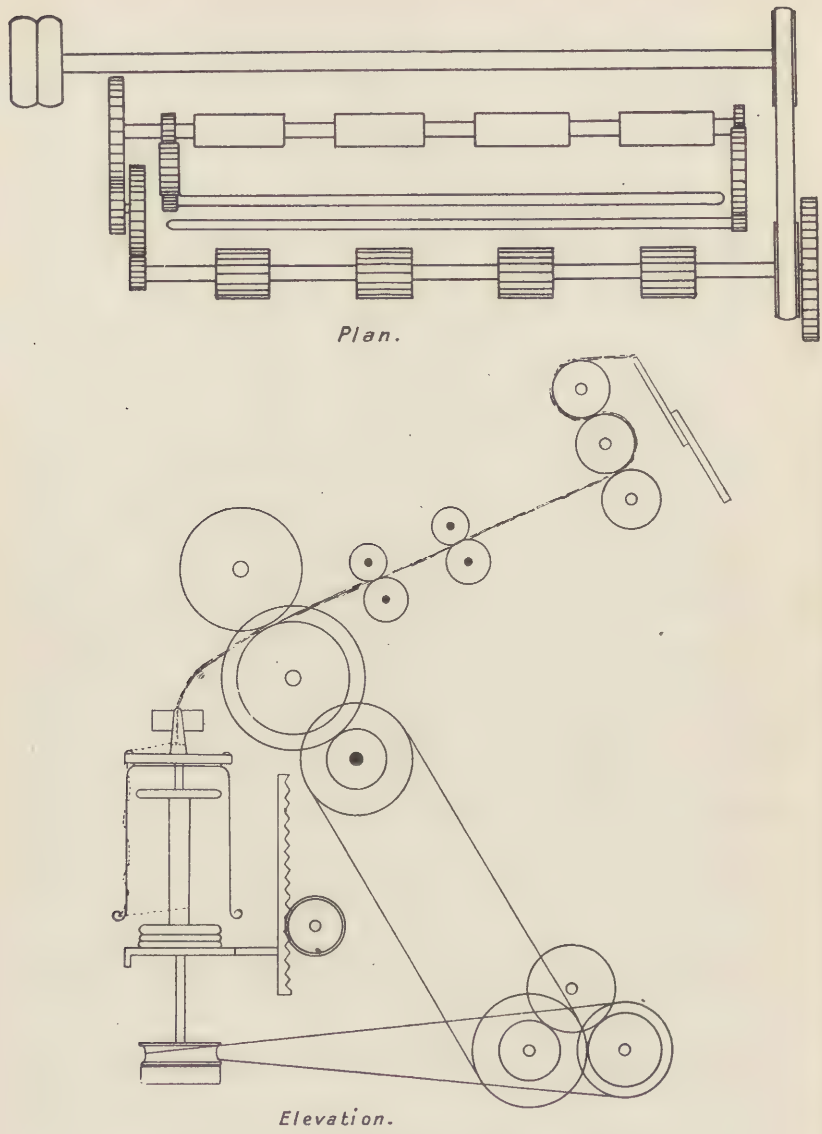


Fig. 35.—Plan and Elevation of a Drawing-box.

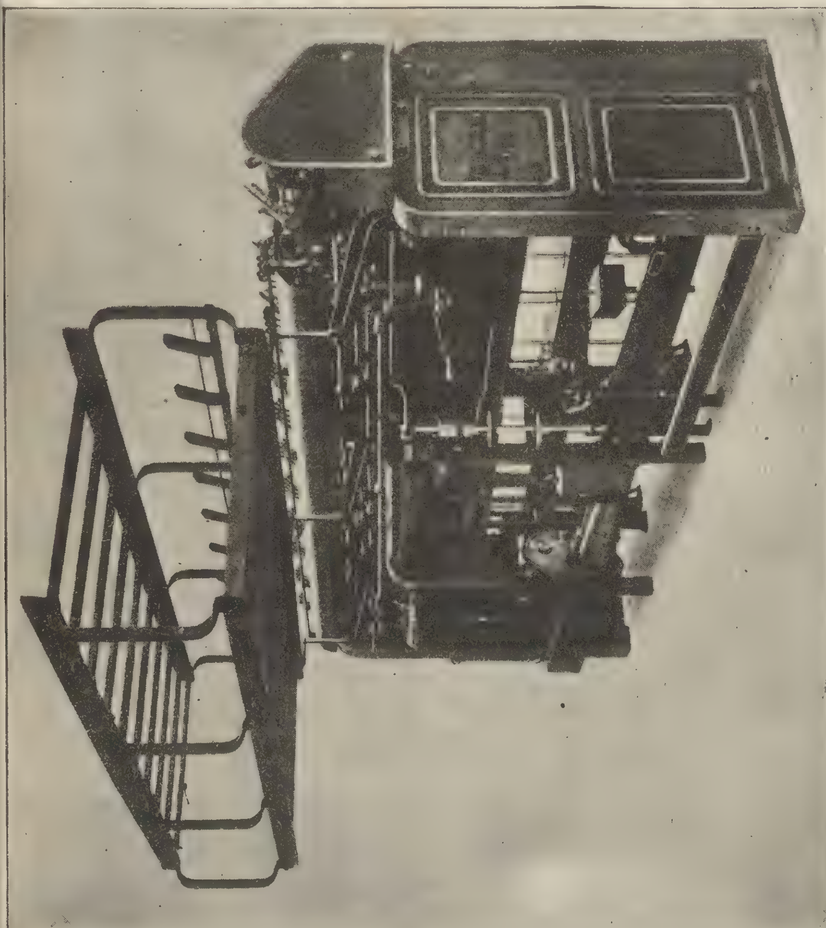


FIG. 36.—Cone Drawing-box.

the scouring machine, the getting of the material into the machine and out of the machine again may be no trifling matter; in fact it may be and in this case is more of a problem than the main operation itself. To put the matter

briefly—in a cone-box the material is positively wound on to suitable sized bobbins with practically no strain upon it, while in the case of the ordinary drawing-box twist must

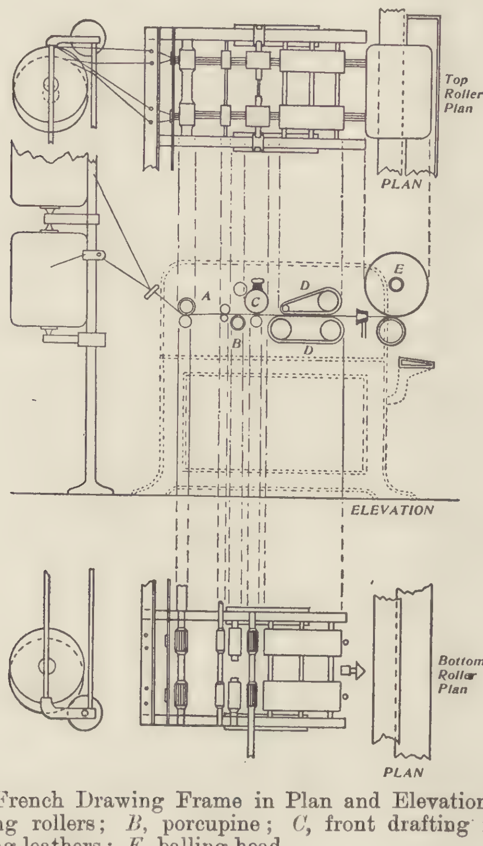


Fig. 37.—French Drawing Frame in Plan and Elevation.—*A*, back drafting rollers; *B*, porcupine; *C*, front drafting rollers; *D*, rubbing leathers; *E*, balling head.

be put into the sliver to give it sufficient strength to pull the bobbin round. It is thus evident that with a cone-regulated wind-on two great advantages accrue—firstly, the

slivers may be drawn much softer and thus a better final spin obtained, and less consumption of power in the machine be required; and secondly, larger bobbins may be employed, resulting in more economical working, especially for large quantities. It is also interesting to note that as both flyer and bobbin are positively driven, bobbin may lead flyer instead of flyer leading the bobbin as ordinarily obtains. The relative advantages of these two methods are worthy of careful consideration.

It is interesting to note that with the cone frame the

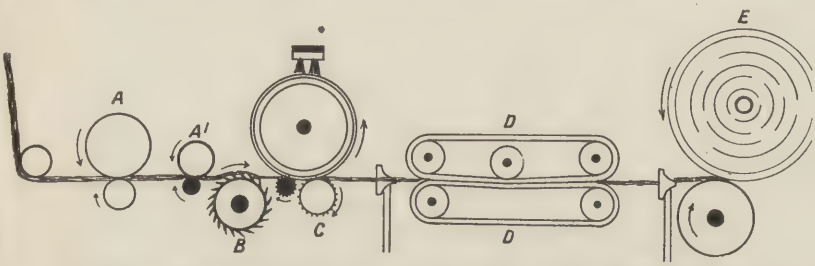


FIG. 37A.—Enlarged View of principal parts in a French Drawing-box.

limit of the strength of the sliver is not in the winding on to the bobbin, but in the pulling of the sliver or roving off the bobbin (see Fig. 36).

The French Drawing-box.—This consists of back-rollers (*A*), porcupine or circular gill or fibre controller (*B*), front rollers (*C*), rubbing leathers (*D*), and delivering head (*E*) (Figs. 37 and 37A). No twist is here inserted, so that a pith-like thread is produced. The arrangement enables doubling and drafting to be effected most readily, and practically does away with the necessity for gills working on screws. The value of this method of producing soft spin mixtures has probably not yet been fully realized in this country.

CHAPTER VII

THE PRINCIPLES OF WEAVING

As previously remarked, the art of weaving, or perhaps more correctly the art of "interlacing," preceded that of spinning. The "wattles" we read of in connection with early methods of building were no doubt willow or other pliant stems of trees or plants interlaced to form a firm foundation for plastering upon. Baskets were similarly made from twigs of suitable thickness, and many other interlacings no doubt preceded the actual art of weaving in the evolution of every race and every country. The idea of actuating in two series all the strands running in one direction, forming a "warp," would soon develop where strands or threads of any required length were forthcoming to form the warp from. The half-heald worked by hand would then appear, followed by the full-heald bringing the feet into play as an aid to the hands. The method of throwing the weft through successive sheds or openings of the warp-threads would similarly pass through many stages before arriving at the present day shuttle and picking apparatus; indeed the fly shuttle itself only appeared in 1738. At first the whole length of warp would be stretched out upon the ground and the weaver would advance as he interlaced the weft from one end of the piece to the other. The idea of beaming the warp on to a roller and of winding up the

cloth as woven in order that the weaver might remain seated in one position and thus work to the greatest advantage is still in embryo in some semi-civilised districts. It is more than probable that long before the hand-loom was in any sense developed very elaborate textures were produced—very laboriously it is true—by hand, almost thread by thread and pick by pick. The art of gauze weaving, for example, was perfectly known to the Egyptians, as in mummy cloths we find some really elaborate styles of this order of interlacing. Pile weaving would also be practised in very narrow fabrics or ribbons. Thus it may be said that the art of weaving passed from the stage when very simple means were employed to effect interlacing, to the stage when very complex hand processes were employed in producing elaborate design; then through a stage in which endeavours were made to markedly increase the output by the hand method, finally culminating in the automatic production of fabrics on the power-loom. It may safely be said that so far as we can tell all the most intricate and pleasing methods of weaving by hand came to England from the Continent of Europe. On the other hand most of the mechanical methods of reproducing the somewhat complicated hand methods went from this country to the Continent. Of course there are exceptions to this, but such are exceedingly few and really trivial.

To-day it may be said that there are practically three kinds of weaving, viz.:—**Unit Weaving**, as illustrated in Axminster carpets; **Group Unit Weaving**, as illustrated in the ordinary loom; and **Average Weaving**, as illustrated in Lappet weaving and in the Electric Jacquard.

The Axminster carpet method of weaving is simply an

imitation of the Oriental knot, as practised in the making of Turkey carpets and in certain Gobelins tapestries, both hand productions. The weaver—if such he may be termed—simply selects from his bundle of yarn the right colour for a small defined section of the carpet he is making, and knots this yarn into that section. As there is no limit to the colours employed and as the structure is firm and well knotted together, the result obtained is usually magnificent. The Axminster carpet loom follows this hand method as exactly as possible. As each individual thread (or perhaps pair of threads) is "latched" by another distinct thread, hence the term "unit" weaving.

The group-unit system results from arranging as many threads as possible in a warp to interlace in the same way, and then to fix these upon the same apparatus—usually a heald-shaft—which thus very simply works them all together exactly as required. Thus if there are 2,000 ends in a warp and plain cloth is to be produced, the odd ends to the number of 1,000 will be mounted on one heald-shaft, and the even ends to the number of 1,000 upon another heald-shaft. Thus each thread is a unit to itself, but there is a grouping of units to effect simplification in production. This system is by far the most frequently employed, and consequently will be dealt with at some length later.

The average weaving method is quite distinct from the other two methods, as no attempt is here made to work each thread with absolute accuracy as in the other two methods. In certain Electric Jacquards,[1] for example, a rough selection of the threads in accordance with the

[1] Carver's Electric Jacquard, at present being tried in the linen districts of Ireland, is an excellent example of this system.

requirements of the design is effected, while in the case of the Lappet frame, although an endeavour is made to work so accurately that each needle places its thread precisely in the cloth, still a rough averaging up only is attained. With more perfect mechanical appliances it is just possible that this system will be much more fully utilised in the future. The Szczepanik designing and card-cutting apparatus forms an interesting attempt in this direction.

Group-Unit Weaving.—In this method of weaving it is obviously necessary that all previous processes to the actual weaving should be perfectly carried out if really satisfactory weaving is to be the result. The first necessity is a yarn which will weave satisfactorily. To obtain this at a reasonable rate becomes year by year more difficult, as the tendency towards cheapness becomes more pronounced. As a rule a yarn with a minimum strength of 4 ounces is the very weakest which should be employed.

The warping operation consists in obtaining a given number of threads (say 2,000), of a given length (say 100 yards), in a given order (sometimes any order will do; sometimes a colour scheme, say four black, two grey, four white, two grey, must be maintained), and at an equal tension, in a convenient form for being wound on to the warp-beam of the loom. Hand-warping is only resorted to for pattern warps. The upright warping mill is still largely employed both for cotton and wool warps, but is frequently inefficient, as it tends to develop stripiness in the pieces—both a sectional stripiness and a distributed stripiness, owing to its failure to control the tension on individual threads unless very carefully set and geared.

The cheese system is still largely employed, but again tends to show a defect in cheese widths, which while not noticeable in fancies, in plains may become very objectionable. The Scotch or horizontal warping mill is gaining in favour and for fancies is practically perfect, but for plains also tends to show a defect in section of the number of bobbins warped with. The warper's beam system, all things considered, seems the most perfect system, as all defects tend to become distributed and thus neutralise one another. This system is simplicity itself for plain warps, and for fancies, with a little arrangement, may also be used to advantage.

Sizing follows warping, the idea being to coat the thread and thus prevent its wearing fluffy in the gears of the loom; and further, if possible, to strengthen the thread. In the past the tendency has always been to put vegetable size on to vegetable fibres and animal size on to animal fibres. To-day, however, the tendency is to put vegetable sizes on to every kind of material, no doubt on account of cheapness. Of course care must be taken that the vegetable size is readily extracted from the fabrics during the finishing operation, otherwise clouded pieces, owing to this irregular sizing, may result. Certain combination warping and sizing machines are placed on the market, but the call for these has rather declined than increased.

After sizing follows dressing, which consists in winding the warp at a uniform tension—both across and lengthwise—on to the loom beam. English dressers prefer to compress the warp on the beam with the tension that the warp itself will naturally stand, but American dressers often attempt to compress the warp still further in order that the

warp beam may be made to carry a greater length of warp, thus saving a certain number of tyings-in.

Drawing or twisting-in follows. If the warp is to be passed through a new set of gears it will have to be drawn by hand through these. A good drawer-in working with a reacher-in passes about 1,000 to 1,200 threads per hour. Should it only be necessary to twist or tye the new warp to the warp—or "thrum" as it is called—already in the gears this may readily be effected either in the loom or out of the loom at the rate of about 1,800 threads per hour. If the warp is plain and no precise order of coloured threads necessary, the recently introduced "Barber-Warp Tyer" will twist or rather tye-in a warp out of the loom at the rate of 250 knots or threads per minute.[1] This machine works on the "average" principle; thus, although almost perfect, it cannot be relied upon to maintain an absolute order of the colours in a fancy warp.

Reference may here be made to the various styles of healds put on the market. It is probable that not nearly sufficient attention is given to this section of the work, as good wearing, easily regulated, and convenient styles of healds are most necessary. Of late wire healds seem to have come much more into use, but there are good and very bad styles of wire healds, so that great care should be exercised in selecting these. Again, a shed full of wire healds means much more weight for the engine to lift.

After drawing-in, "sleying," or the passing of the threads singly or in groups of two, three, four, five or six through the reed is necessary. This is effected at the rate of about

[1] A mechanical "drawing-in" machine is now placed on the market.

2,000 threads per hour by means of two sleying knives worked alternately by hand. Reeds again should receive more attention than they at present claim. English reed makers can make a good ordinary article, but German and French reed makers are much ahead in the production of really fine reeds with properly feathered dents regularly soldered together.

After the warp has been passed through the gears and reed the warp-beam and gears must be lifted into the loom—the gates in the loom shed being sufficiently wide to ensure this without damage to either warp or gears, the gears hung in position, the reed placed in position, the warp attached to the cloth beam by means of a level wrapper, and then after the necessary gearing up the actual operation of weaving ensues.

The principal movements during weaving are as follows:

Shedding, or forming a passage for the shuttle through the warp threads, certain of the threads being definitely raised and the others depressed; threads lifted and depressed being varied for a succession of sheds.

Picking, or the throwing of the shuttle through the shed which has been formed, leaving the pick behind it in the shed.

Beating-up, *i.e.*, the reed beating the pick just inserted up to the cloth already formed to make a firm, even texture.

Letting-off, *i.e.*, unwrapping warp from the warp-beam to take the place of that used up in interlacing with the weft to form the cloth.

Taking-up, *i.e.*, winding up on to the cloth beam the cloth woven, this movement of necessity being worked in conjunction with the letting-off.

The following accessory mechanisms are practically necessary to ensure economical and satisfactory work:

The Boxing Mechanism, by means of which any required colour of yarn is presented, in its shuttle, on the picking plane and thus thrown into the cloth as required.

The Stop-Rod or the Loose-Reed-Mechanism, through which the loom is brought to a standstill should the shuttle fail to reach the box, serious breakage of warp threads thus being avoided. The first style is applied to plain or rising box looms, the latter to circular box looms.

The Weft-fork Mechanism, which only permits the loom to go on with its work while weft is presented to it. Should the weft be broken or absent the loom is immediately brought to a standstill. There are two forms, the side-weft fork for plain looms and looms with boxes at one end only, and the centre-weft fork for double box looms.

The Warp-Stop Mechanism, by means of which the loom is brought to a standstill should any warp-thread break.

The Spooling or Shuttling Mechanism, by means of which when the cop of yarn placed in the shuttle is finished or about to be finished either it or the whole shuttle is automatically ejected and a fresh spool or shuttle pushed in to take its place without stopping the loom or without the intervention of the attendant.

Before describing certain typical looms placed upon the market reference must be made to the various methods of effecting the primary weaving movements and also to certain points of importance with reference to the accessory mechanisms.

Shedding.—To the uninitiated this may seem a simple matter requiring little consideration. Perhaps this would

be so were the yarns which it is necessary to weave always strong and were time no object. But yarns must sometimes be woven which will hardly stand dressing, and looms must run from 80 up to 300 picks a minute—although a high

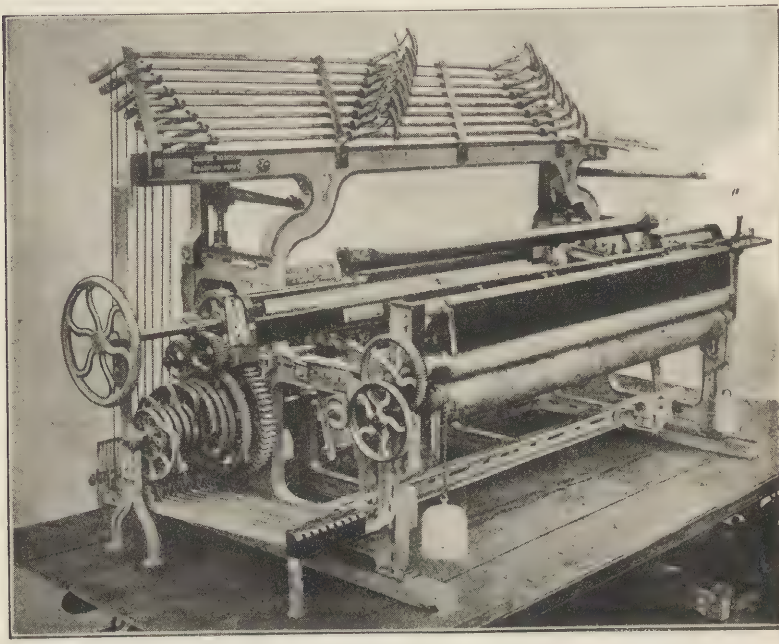


Fig. 38.—Tappet Loom with outside treading.

speed is by no means always economical—and thus it comes about that most careful and detailed consideration must be given to every point in the shedding mechanism. The chief points for consideration are—firstly, the method of selecting the healds to be raised and the healds to be lowered—absolute certainty must here be ensured; secondly,

the movement of the healds to put as little strain as possible into the warp threads during the change of shed; and thirdly, the satisfactory holding of the threads up and the threads down during picking to ensure the safe passage of the shuttle. Of the varied mechanisms to effect this, the Tappet mechanism (either inside or outside tread, with

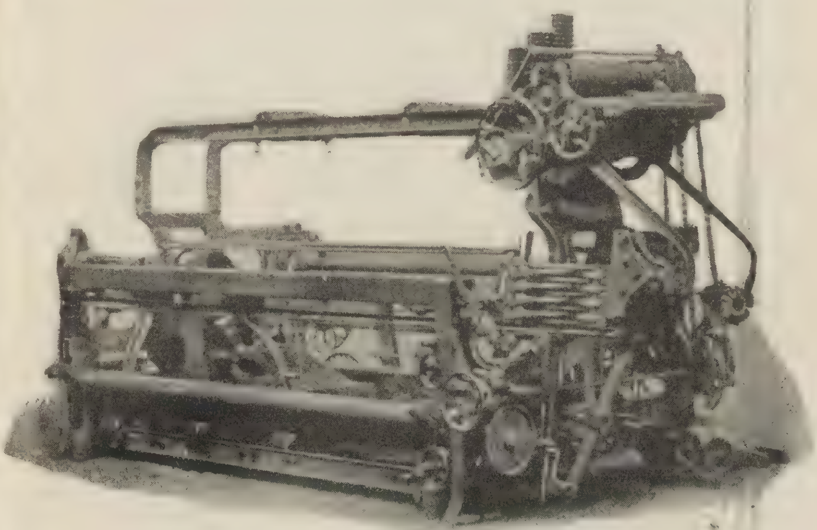


FIG. 39.—Heavy Coating Loom.

" top " or " under " motion) is the simplest and most satisfactory, as the curve for the " rise " and for the " fall " of the heald-shaft can be made to give a simple harmonic motion or any other desired motion, while the " dwell " of the heald-shaft may be regulated to a nicety. (Fig. 38.) Unfortunately, the interlacing or figuring capacity of the Tappet loom is not great, so that for anything above a

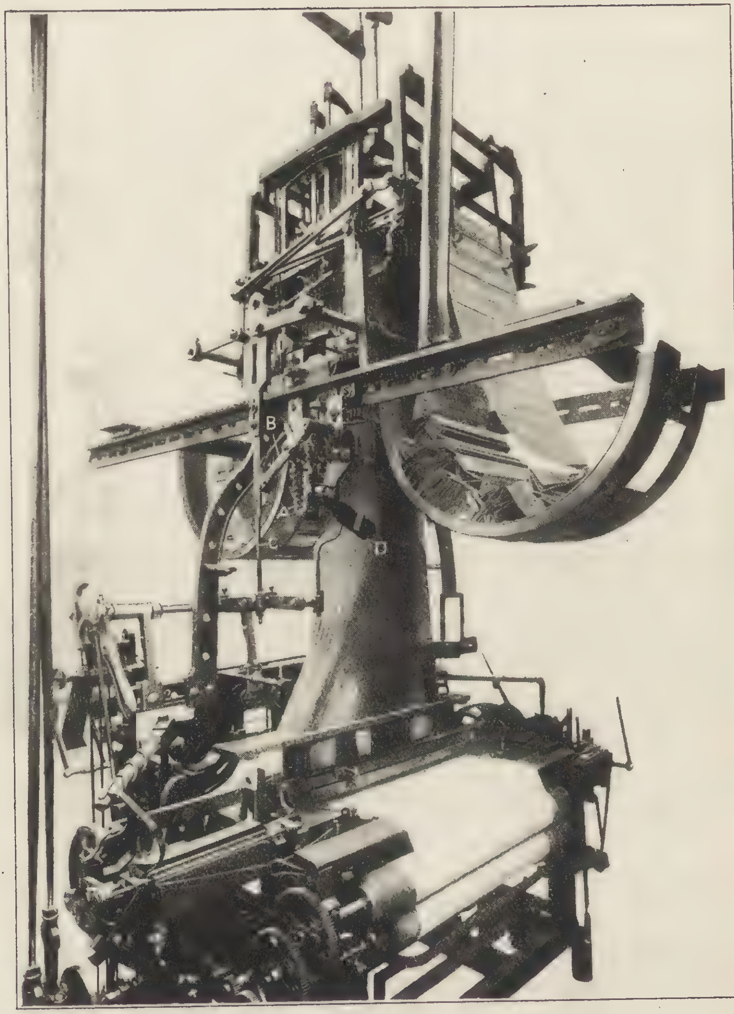


FIG. 40.

weave repeating on 12 to 16 shafts a Dobby must be

employed, while for anything above, say, 36 shafts, a Jacquard is employed. The shedding arrangements of Dobby looms are usually in some sense an imitation of the Tappet action (see Fig. 39), but the following variations are to be met with: close shedding and open shedding Dobbies, single-lift and double-lift Dobbies, with combinations of the same. Each possesses certain advantages either for the fabric being produced or in quick and perfect running. The only difference in principle between the Dobby and the Jacquard is that in the Dobby each heald-shaft may usually be controlled positively whether lifted or depressed, while in the Jacquard the lifting only is positive, the depressing being effected by weights on the harness cords. The usual figuring capacities of Jacquards are—Bradford, 300 or 600; Huddersfield, 400; Belfast, 1,200 to 1,800; but there are naturally variations from these precise numbers in each district and for specific purposes. (See Fig. 40.)

Weaving wages largely depend upon the shaft or harness capacity of looms.

Picking.—The throwing of the shuttle through the shed—under the guiding influences of the shuttle-race and reed—is a most difficult and important matter. If thrown too strongly it is liable to break the weft yarn and to wear itself and the loom out quickly, and if thrown too weakly the loom knocks off. Again, the tendency of shuttles to fly out of the shed has necessitated the adoption of shuttle-guards to protect the weavers. There are two main types of picking motions, viz., over and under. The over-pick is the "sweeter" and safer, but unfortunately consumes a large quantity of picking-strap. The under-pick partakes less of the slinging character than does the over-pick, so

that for the weaving of lightly-twisted weft yarns such as mohair and alpaca the over-pick system possesses marked advantages.

Beating-up.—Sufficient attention is not paid to this motion by many loom makers, as the satisfactory running of the loom may largely depend upon the satisfactory running of the going-part which carries the shuttles, etc., as well as the reed. The points to be carefully considered are—sweep of crank, length of connecting pin, method of attachment of connecting pin to sword-arms, and the relationship of sword-arm connections to crank centre.

Letting-off and Taking-up.—These two mechanisms are usually worked in conjunction, for what the cloth requires must be delivered to it by the warp-beam. Both these mechanisms may either be positive or negative, but usually the taking-up motion is positive (so that the wefting of the cloth is perfectly controlled) and the letting-off negative. The latest form of positive letting-off motion, however, in which the tension of the warp itself regulates the letting-off, has proved a marked practical success and is nearly always adopted for heavy wefting. For lighter work and even for some forms of heavy work the ordinary or special form of negative letting-off motion is adopted. The taking-up of the cloth woven is almost invariably effected by means of a friction or sand roller (which bears upon the cloth beam, and thus turns it by friction at a fixed rate, notwithstanding its increase in circumference) driven through a train of wheels, the last one of which receives its movement from a pawl on the sword of the going-part. One or more of these wheels may be changed to give the required number of picks in specific cloths. In the best train there is a direct

relationship between the picks per inch and the teeth in the change wheel.

The Boxing Mechanism.—Boxes are made in two forms—rising and falling, and circular. In rising boxes there is no limit as to size or number, while in the case of circular boxes there is a distinct practical limit in size, and it is not as a rule convenient to have more than six boxes to the round. Thus, for heavy thick materials rising boxes of great size are employed; while for fine cotton, silk, etc., the smaller circular boxes are mostly used.

Looms are made in three forms with reference to their boxes, viz., without boxes, *i.e.*, plain looms; boxes at one end only; and boxes at both ends. In looms with boxes at one end only there are limits in colouring, as only double picks may be inserted without very special arrangement and loss of time, while in one most important type of circular box there is a further limit as to which colours may be presented on the picking plane.

The addition of boxes to a loom usually reduces its speed from 5 per cent. to 10 per cent. and necessitates the payment of a slightly higher wage to the weaver.

The Stop-rod and Loose-reed Mechanism.—Plain and rising box looms are fitted with the stop-rod mechanism, while circular box looms are fitted with the loose-reed mechanism. In the stop-rod mechanism the reed is prevented from coming within less than, say, 4 inches of the fell of the cloth, unless the shuttle is in the box, by means of a stop-rod which plays against a special casting, termed the "frog." As the shuttle normally enters the box, however, it lifts this stop-rod clear of the "frog" and so the loom proceeds with its task. Should the shuttle fail to reach the

box and stop in the shed, the loom is knocked-off by means of the stop-rod coming against the special casting or "frog," which, in turn, acts upon the setting-on lever and loom brake. Few or no warp threads will be broken down, as the reed cannot get nearer than about 4 inches to the fell of the cloth—a distance which is just judged sufficient to save breakage of warp threads when the shuttle is left in the shed.

In the case of the loose reed mechanism the shuttle is allowed to knock the reed out to prevent the reed breaking the shuttle through the warp threads. To allow of this the reed is only lightly held until it is within, say, 2 inches of the cloth—when, if the shuttle were there, the reed would be forced out and the belt thrown on to the loose pulley—after which it is firmly locked for the beat up. Owing to this locking and unlocking of the reed heavy wefting cannot be effected by this mechanism.

The Weft-fork Mechanism.—In plain looms this is at the side, close to the setting-on handle. It consists of a small three-pronged fork passing through a grid in the going-part, across which grid the weft has to pass. If the weft be present it does not allow the prongs of the fork to pass through the grid, but, instead, tilts the fork. At this moment a hammer head is drawn back by means of a projection on the low shaft of the loom (once every two picks), but nothing happens if the weft is there and has tilted the fork. If the weft is not there, however, the fork is not tilted and a catch upon its extremity is caught by the hammer head and the loom thus brought to a standstill. Mr. Pickle, of Burnley, has patented a markedly improved form of this fork which mechanically may be considered perfect, and this cannot be said of the ordinary form.

The centre weft-fork mechanism—which must be employed when there are boxes at both ends—acts through the weft supporting if present, or allowing to fall if absent, a lightly-weighted fork, which, by means of a slide, is connected with the setting-on lever.

The Warp-stop Mechanism.—While the weft-stop mechanism has always been considered as essential to the satisfactory running of a loom, the warp-stop mechanism has never been in favour, and obviously it can only be of economical value in the case of weaving tender warps (when possibly it helps to break down threads) or where one attendant looks after a large number of looms. With the comparatively recent introduction of the automatic loom, warp-stop methods have increased in favour, but their application in anything but very plain work is still comparatively rare.

There are two forms placed on the market—the mechanical and the electrical. The chief objection to them is the time taken in readjustment when drawing in a new warp, while, of course, it is conceivable that they may in all warps occasionally cause ends to break down. Possibly the greatest advantage lies in that a weaver cannot produce an imperfect piece as the loom will not run with ends down.

The Spooling or Shuttling Mechanism.—This is the mechanism of most recent introduction, although so called automatic looms were tried about forty years ago. If one weaver is to attend to sixteen or twenty-four looms, it is evident that there must be some self-shuttling arrangement, or there will always be some looms standing. On the other hand, the additional mechanism involved may necessitate additional attention on the part of the tuner or overlooker

—usually a high-wage man—and hence he will not be able to follow so many looms.

In the cotton trade the Northorpe loom—one form of the automatic loom—is being largely adopted, the spool ejecting mechanism being brought into play by the weft running off, so that each change of spool may be accompanied by a broken pick in the piece. This broken pick would be a serious defect in cloths other than cotton, so that some means to indicate for the ejection of the spool before all the weft has run off must be adopted. On the other hand, spools must not be ejected before the weft is practically run off, or the waste will be too great. The latest system of effecting this is by means of a special split bobbin held together by the weft. The pike of the shuttle is so designed that it gently bears upon the split bobbin, but only succeeds in opening it just as the last layers are taken off. The opening of the bobbin brings into action the spool ejection mechanism, the old spool or bobbin is ejected and a full one automatically taken from the reservoir and put in its place without interfering with the running of the loom.

The classification of looms is based chiefly upon the type of shedding mechanism, but sometimes upon the boxing capacity. Thus looms are usually classified as Tappet, Dobby, or Jacquard looms, but manufacturers of tweeds and coloured fancy goods naturally think more of the boxing capacity than of the figuring capacity, as they usually only require a four or six thread twill weave, depending upon colour as a means of beautifying their fabrics, although, of course, the colour is usually applied to a good sound structure.

The outside tread Tappet loom is most largely employed in Yorkshire for all classes of simple interlacings, including such light weight goods as Orleans, Italians, cashmeres, serges, etc. The inside tread Tappet loom is more largely employed in the Lancashire cotton trade for all styles of simple cotton fabrics, and in broad looms for heavy Yorkshire woollens.

The Dobby loom—of various types and makes—is employed in both Lancashire and Yorkshire for fancy styles, which are not floral, but rather fancy in the sense of being compounded of more or less intricate interlacings.

The Jacquard loom is employed when elaborate figuring is necessary, as in this loom from 100 to 1,800 threads may be controlled individually by means of cards with holes cut or uncut to produce the required pattern.

For special purposes combinations of the three types are frequently met with. In tapestries, for example, the Jacquard is frequently mounted in conjunction with a Tappet or a Dobby; for skirtings Tappets and a Dobby are frequently combined, while boxes may be employed in conjunction with any and every shedding combination, sometimes the relationships of Jacquard, Tappets, and boxes being very complex, but really most delightfully controlled; from which it will be gathered that the weaver who can perfectly control such a combination is no mean, unintellectual person, but rather must be regarded as a truly matured craftsman possessing at least some of the qualities of the methodical scientist.

CHAPTER VIII

THE PRINCIPLES OF DESIGNING AND COLOURING

As it is generally recognized that the perception of form precedes that of colour it is more than probable that the first attempts at woven decorations would take the form of diagonals, stripe and check effects, possibly produced by interlaced rushes or bands.[1] Just as the Norwegian peasant takes out his knife and carves the wooden wall by the side of his chair so would our ancestors amuse or profit themselves by schemes of interlacings with such materials as were to hand. Thus we can well imagine the various natural shades of wool such as are indirectly referred to in early Biblical history for example, affording opportunities for the development of design in form long before artificial colours made their appearance. For the sake of variety various kinds of materials would next be tried, and so a second factor of interest would be introduced. Finally, the appreciation of colour would be developed and attempts made at colouring the raw materials by such herbs, etc., as were available, or rather of which the colouring properties were known. For it must have been a grievous thing to the ancients to discover that red poppies would not yield their colour, that Tyrian purple must be sought

[1] The Scotch plaid was originally a plait or possibly a number of interlaced plaits.

for in a mollusc and not in the gorgeous garb of nature. As has been already pointed out, the inborn love of man for artistic productions was developed long before the present-day economic spirit; hence artistic weaving was developed at a very early date and was followed much later by attempts, firstly, at quicker production of artistic patterns, and, secondly, by attempts to produce goods more economically and by simpler means. A relic of this evolution is in evidence to-day in the fact that so far as the art of designing and weaving is concerned England is absolutely indebted to the Continent, everything good coming to us from Italy, France, the Netherlands, or Germany. On the other hand, so far as economical production is concerned, the Continent is indebted to England, we leading the way in all power machinery. Curiously enough, America led the way during the last century in devising means for the quicker production of elaborate styles, as instanced in the plush wire loom and the Axminster carpet loom. This was, no doubt, due to the enormous wealth so rapidly developed resulting in a great call for what might be regarded as luxuries.

Present-day textile design may be very conveniently studied under its three factors—material, interlacing, and colour. Of course, there are many varied combinations of two or more of these factors, but brief study will prove that these factors are really the key to the thorough comprehension of all textile design, and that consequently each merits careful consideration.

Materials.—These briefly are animal, insect, vegetable, mineral, and artificially produced fibres or filaments. Among the animal class are specially to be noted all the

varieties of wool, mohair, alpaca, vicuna, cashmere, camels' hair, horsehair, rabbit fur, etc.

A special class is made of the insect fibres, seeing that they are so valuable and useful, and further that from the point of view of chemical reaction they cannot quite be classed with the true animal fibres. Cultivated and wild silks are the chief representations, while certain "spider" silks and other varieties of cocoons are continually making their appearance.

The vegetable fibres may be divided into two very distinct classes—viz., the fluffy seed hair types of which cotton is the principal representative, but of which various "thistle-down" and other fibres keep putting in an appearance; and the stem fibres, such as flax, hemp, jute, china-grass, etc. Plants themselves, as notably the mosses, also are sometimes spun and woven.

The mineral fibres are principally metallic threads, and such special minerals as asbestos and silica, which are specially spun and woven into fabrics for fire-resisting and other purposes and in the form of glass for pure novelty.

The artificially produced fibres include artificial silk, artificial linen, paper, and, latest of all, some organic or crystalline forms of other substance somewhat of the same character as asbestos, which lately have been successfully produced in Germany.

It should be further noted in this connection that it is not sufficient to simply consider the raw material. The manner in which it has been prepared and spun may create differences as marked as the differences between some of these distinct classes. For example, there may be a greater difference between woollen and worsted yarns and

net and spun silk yarns than there is between raw wool and cotton. The arrangement of the fibres in the threads of which a fabric is composed, while not directly affecting the interlacing, may nevertheless indirectly cause the designer to adopt specific styles of interlacing to develop a particular characteristic in the resultant cloth; so that it is customary to pay particular attention to this apparent detail, and especially to consider the conditions of twist in both single and twofold yarns. If, for example, three lots of two 40's black botany yarns are twisted 7 turns, 14 turns, and 28 turns per inch respectively, in the woven fabric they will show a marked difference. If the yarn be black and white twist not only will there be a difference in texture, but also in the speckled appearance of each lot of yarn as it appears in the piece. The direction of twist of warp and weft and also in relationship to twill interlacings is also very important.

Interlacing.—There are three recognized methods of producing fabrics—viz., by felting, by knitting, and by weaving. Felt fabrics are essentially fibre structures. Perfectly mixed and equalized films of wool are superimposed one on the top of the other until a sheet, say, 40 yards long, 60 inches broad, and 4 inches thick, of a more or less "fluffy" nature, is produced. This under heat and acid is hammered, milled, or felted into a comparatively thin texture known as "felt."

Knitted textures usually consist of one thread interwoven with itself, but there are now varieties of knitted fabrics which do not entirely fulfil this condition. The above two classes, although most important, must in this work give precedence to the third class, the "woven" fabric.

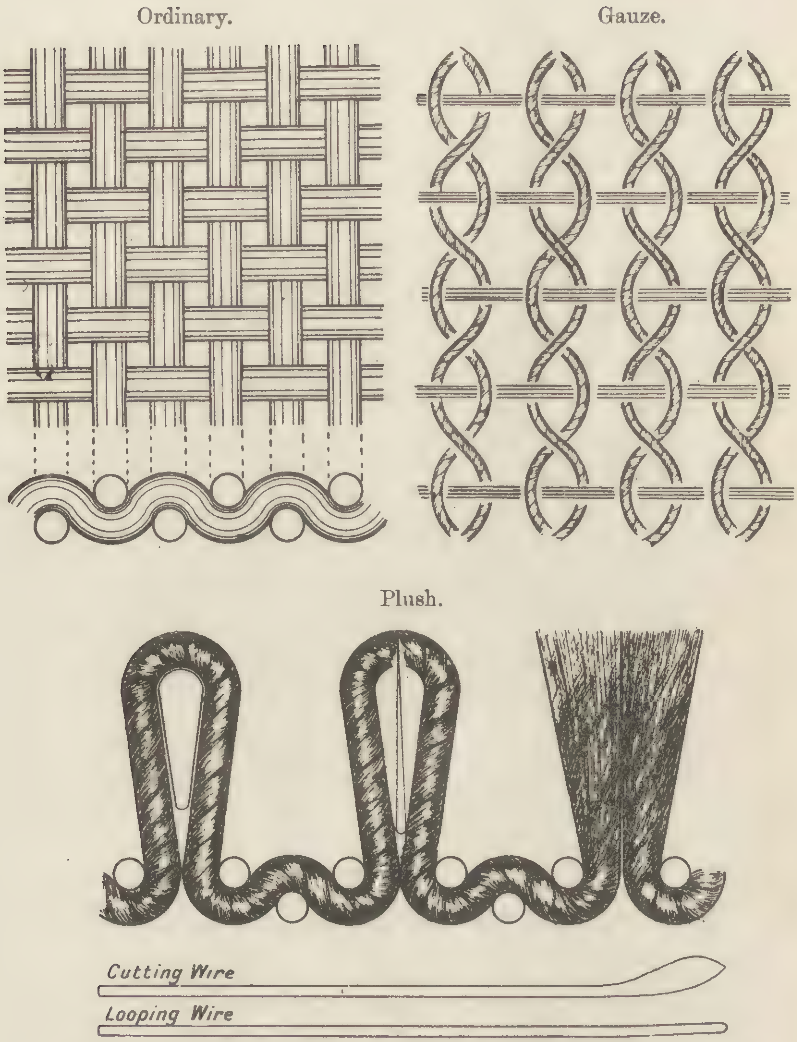


FIG. 41.—Ordinary, Gauze, and Plush Interlacings, *i.e.*, straight thread, curved thread, and projecting thread structures.

Of woven fabrics it is evident that there will be three varieties, along with their combinations, viz., straight thread fabrics, curved thread fabrics and projecting thread fabrics, having their representation in the ordinary woven texture, the gauze texture and the plush texture respectively. (See

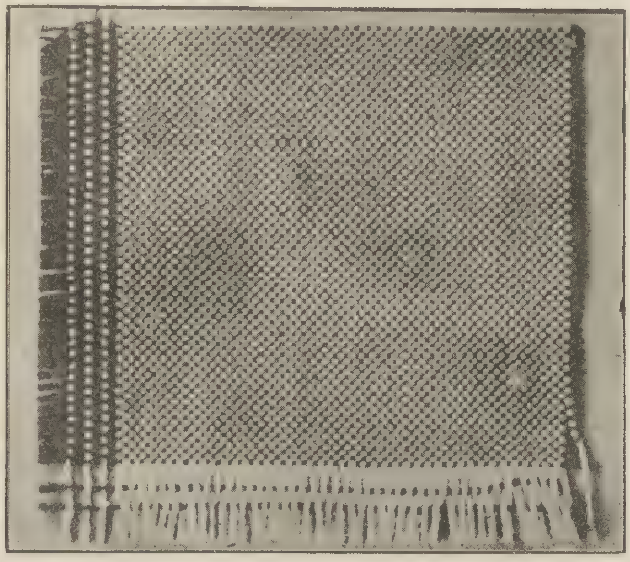


FIG. 41A.—Showing, with a Fabric composed of White Warp and Black Weft, Plain Weave Interlacing.

Fig. 41.) There are also certain special styles which do not well come within the range of any of the above three classes; but these may best be considered as exceptions after the above three classes have been fully studied. All the woven fabrics increase vastly in interest if regarded as

"a mass of balancing strains." The adoption of this attitude results in most interesting developments, especially with reference to curved thread or gauze fabrics.

Of the straight-thread or ordinary fabrics the following variations are to be noted :—

(*a*) Variations in the makes of plain cloths, hopsacks, etc.

(*b*) Rib cloths, plain and fancy, in both warp and weft direction ;

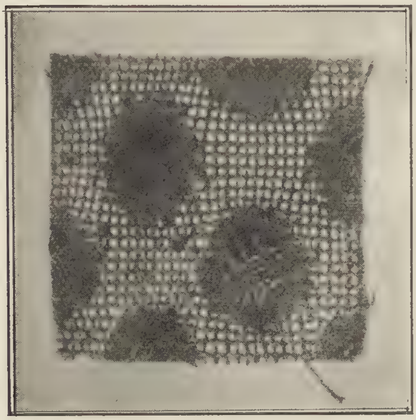


FIG. 41B.—Gauze Ground Fabric upon which a Plain Cloth and Weft Flush Figure is Thrown.

(*c*) Twill cloths, both plain and fancy ;

(*d*) Rib-twill cloths of the "corkscrew" type ;

(*e*) Sateen cloths, warp or weft face of various qualities ;

(*f*) Crêpe cloths, the antithesis of the sateen cloth ;

(*g*) Spotted cloths based on the single cloth structure ;

(*h*) Figured cloths based on the single cloth structure;

(*i*) Extra warp or weft, or warp and weft figured cloths;

(*j*) Double cloths or treble cloths for figuring or adding weight, or for both figuring and weight.

In Figs. 42 and 42A illustrations (enlarged) of the chief of these varieties are given.

There are many varieties in each of the foregoing classes, but as such would require a treatise larger than

the present the reader is referred to the author's work on "Textile Design," and to "Designing for Shaft Work," by F. Donat, of Vienna (published in German only).

Of curved thread or gauze fabrics the following variations are to be noted :—

(*a*) Variation in the number of threads crossing: one

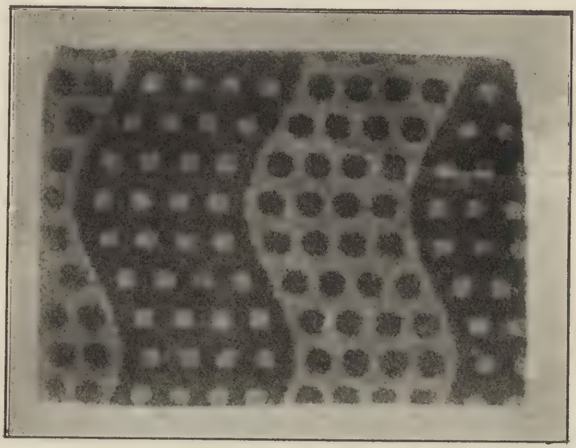


Fig. 41c.—Plush Fabric.

crossing one, two crossing two, one crossing three, one crossing four, etc.;

(*b*) Variation in the number of picks grouped together and in the manner in which they are grouped together by the crossing threads (see Fig. 43 and 43a);

(*c*) Variation in the yarns—thicknesses, colours, etc.—woven together (see Fig. 43b);

(*d*) Variation in the crossings—leno, gauze, plain—which may be woven together;

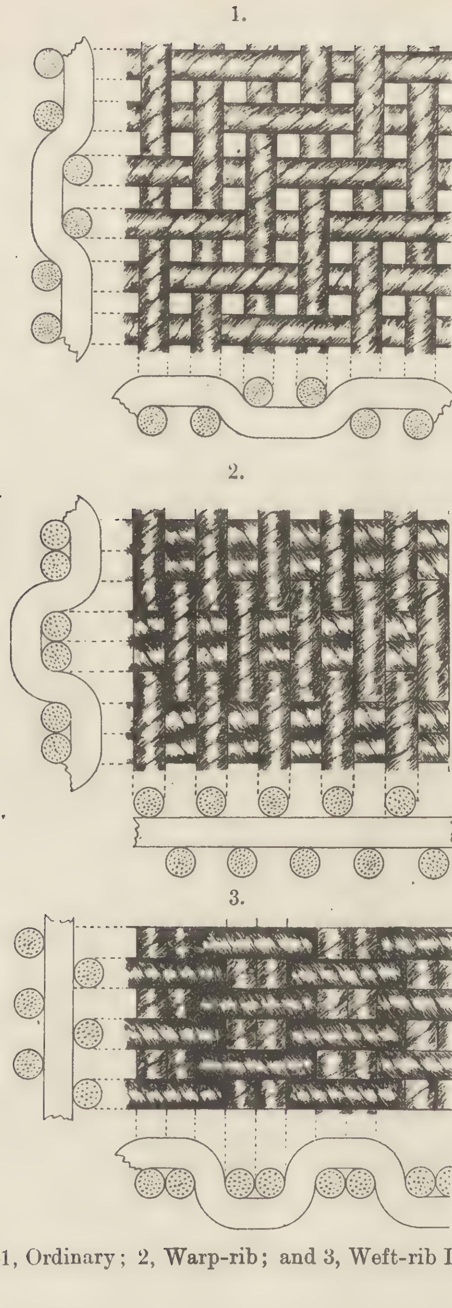


Fig. 42.—1, Ordinary; 2, Warp-rib; and 3, Weft-rib Interlacings.

(*e*) Variation in figuring by various gauze or gauze and ordinary interlacings (see Fig. 41B);

(*f*) Variation by the introduction of extra materials (see Fig. 43C);

(*g*) Variation producible by employing double-gauze structure (see Fig. 43D);

(*h*) Variations by combining gauze and pile structures.

Again, each of these classes has many varieties which cannot be dealt with here.

4.

5.

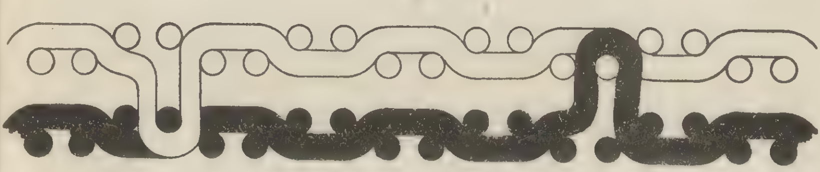


FIG. 42A.—4, Weft-back; and 5, Double Cloth Interlacings.

Of projecting thread structures usually termed "pile" fabrics the two great varieties are warp and weft piles. The former, as will be realized by referring to Fig. 44, are formed by pulling up the warp out of the body of the cloth during weaving, usually by means of wires, to form a brush-like or "pile" surface. The latter are formed by floating certain picks over the surface of an otherwise firmly-woven piece and then throwing these floats up as curls by shrinking the ground texture or as a cut pile by severing these floats either in or out of the loom. In this latter

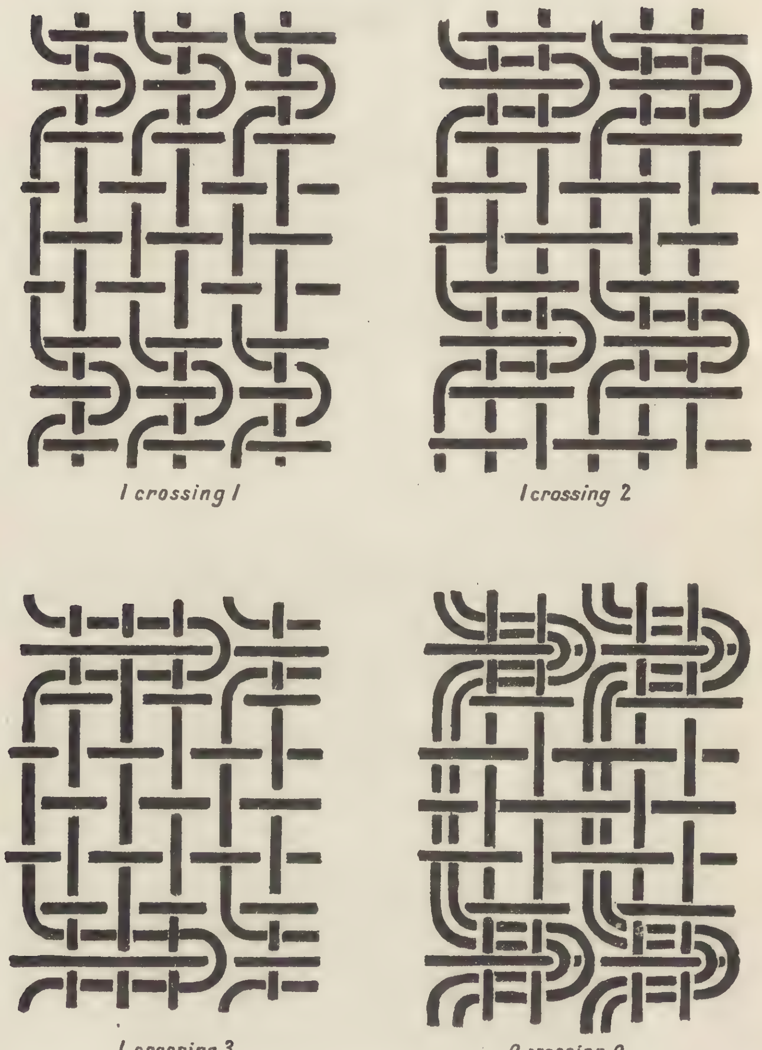


FIG. 43.—Four Varieties of Simple Gauze Crossings.

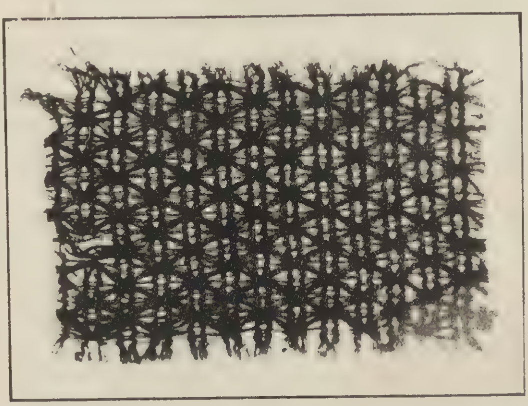


FIG. 43A.—Gauze Structure with Grouping of the Picks as the Characteristic Feature.

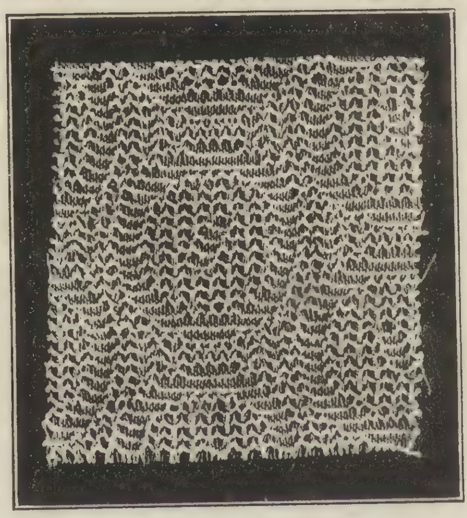


FIG. 43B.—Gauze Structure with Fancy Yarn Introduced.

case some most useful types of pile fabrics are obtained —fustians and corduroys for example—by distributing or concentrating the pile on certain sections of the cloth by the suitable arrangement of the positions where the floating picks are bound into the fabric.

Of pile fabrics the following varieties are to be noted :—

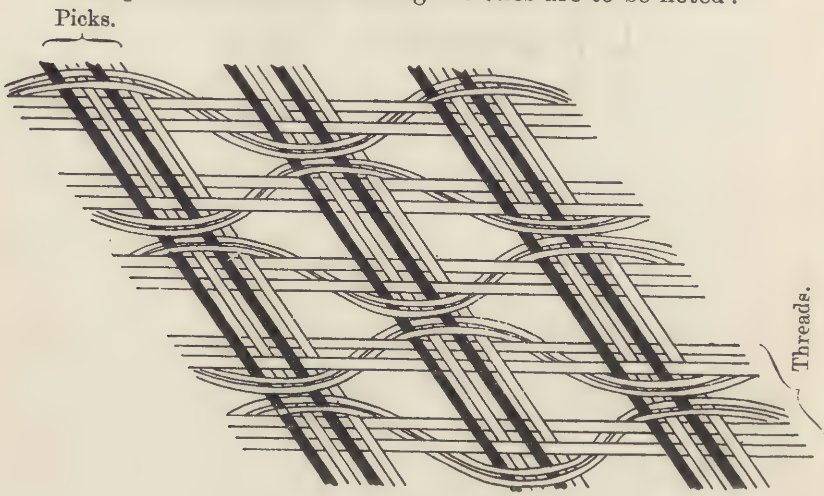


Fig. 43c.—Double Weft Gauze.

(*a*) Variation in density of pile, so that the ground texture may show through or may be completely hidden ;

(*b*) Variation in length of pile;

(*c*) Variation by the use of cut and looped pile—the difference between the same coloured yarn cut and looped being ample to design with (see Fig. 41c) ;

(*d*) Variation in the form taken by the cut, or looped, or cut and looped piles, such as stripes, checks and figures.

Perhaps in this class a special section should be devoted to varieties of piles produced on the "double-plush"

principle as illustrated in Fig. 45; but as these generally speaking lend themselves to the same variations as the other pile fabrics already dealt with, they are considered together. There is no single work which fully treats the

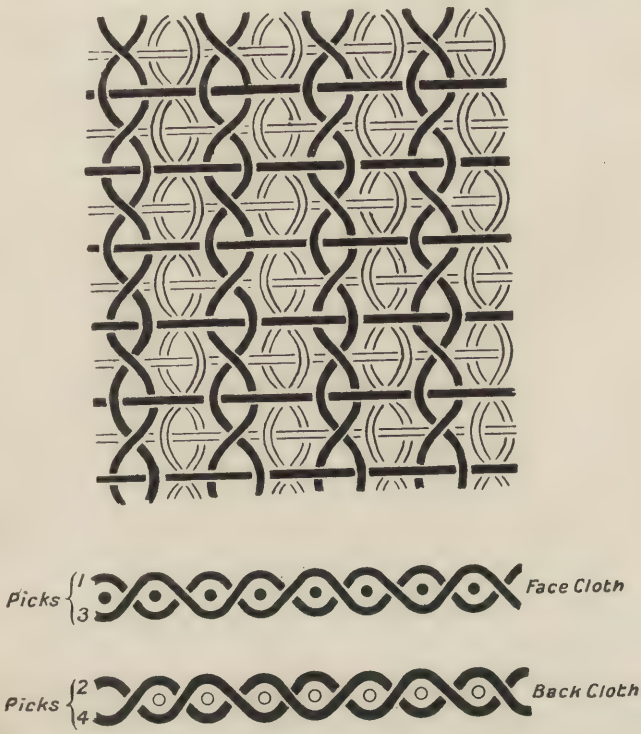


FIG. 43D.—Double Gauze Interlacing.

three sections of warp piles, weft piles and double piles; but the work of Donat already cited may be consulted with advantage.

The Use of Point-paper.—To facilitate designing squared or point-paper is employed Briefly it consists of spaces

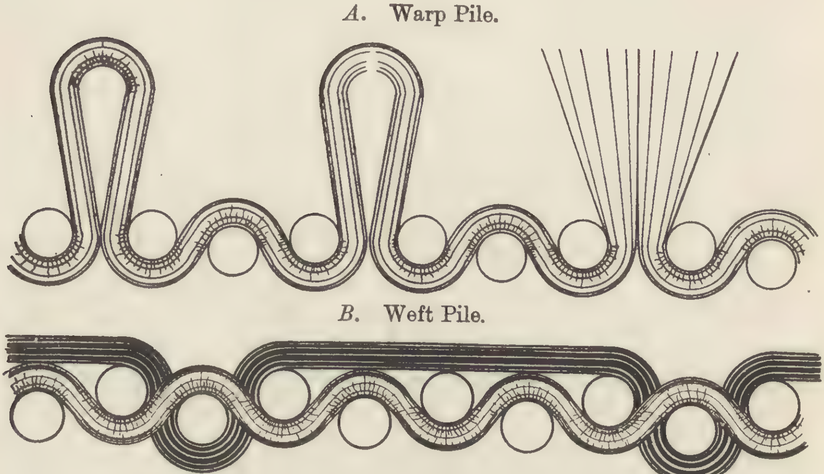


FIG. 44.—Two Types of Pile Fabrics.

lengthwise, representing warp threads, and spaces cross-wise representing weft threads, or "picks," as they are termed. *This paper must not be regarded as so many squares,*

FIG. 45.—Illustrating the Production of Double Plushers, *i.e.*, Two Single Pile Fabrics, face to face.

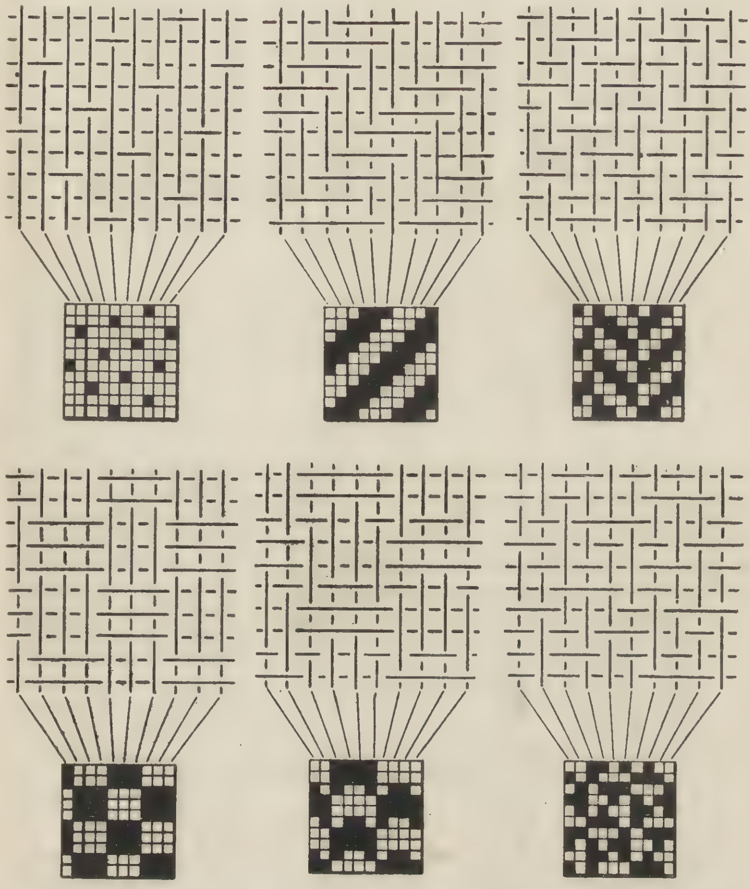


FIG. 46.—Example of the Representation of Simple Interlacings on Point or Square Paper.

but as warp threads—say of a white material—under which lie so many weft picks—say of a dark material. Then whenever weft is required to come over warp, that particular

section—*in this case a square*—is marked black. Thus to the well-versed textile designer the point-paper weave does 'airly correctly represent the actual appearance of the cloth, although it is obvious that such weaves must be viewed through the eyes of the designer's many and varied experiences. To further elucidate these somewhat brief remarks six examples of interlacing, with their respective paint-paper plans, are given in Fig. 46.

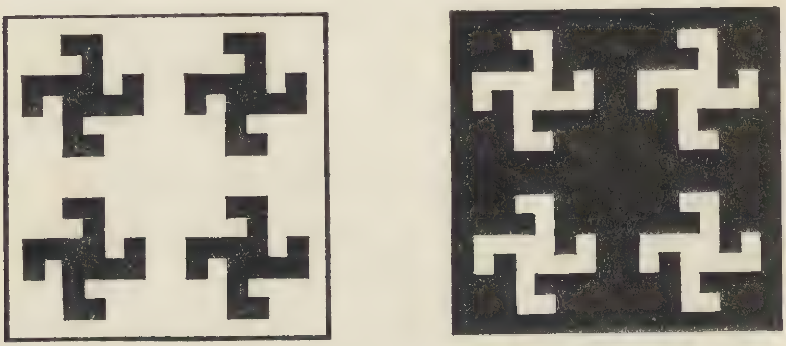


Fig. 47.—Example of the Reversing of Pattern due to Defective Grading of Colour Ranges.

Colour.—Colour may obviously be applied to all the foregoing fabrics. So subtle is the colouring of textiles that the designer well versed in the colouring of one class of goods may, nay, probably will, be unsuccessful in the colouring of another class of goods.

In the abstract colours should be apportioned to the fabric for which they are designed; they should be appropriate and artistic in themselves if solid shades, and in their combinations for multi-coloured styles. Note should also be made that colours cannot be considered irrespective of luminosities,

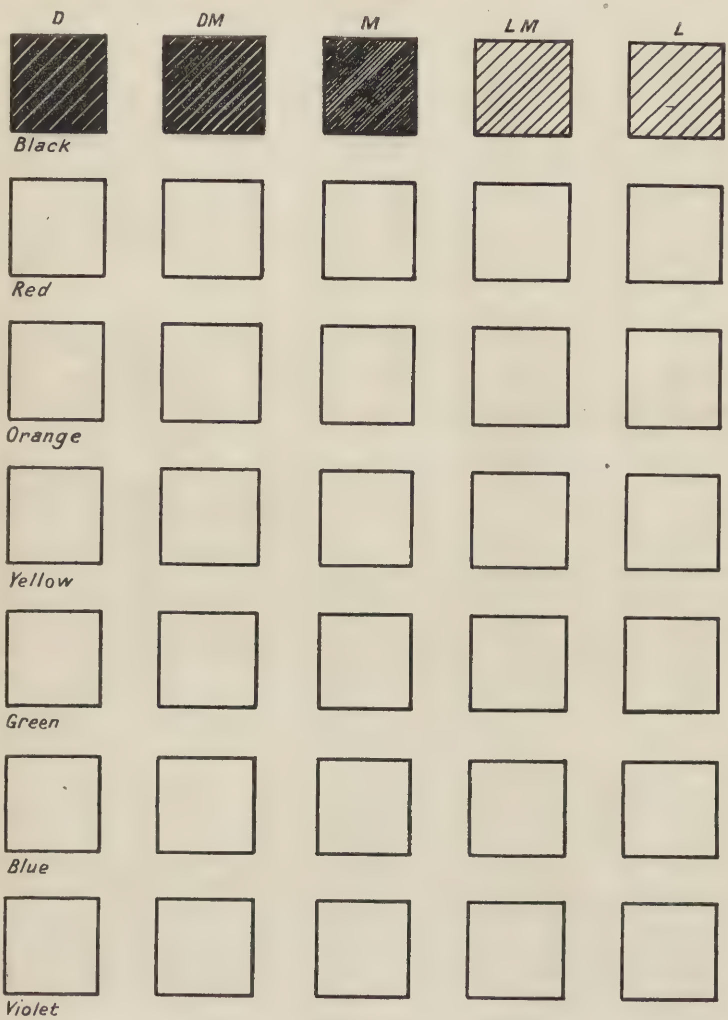


FIG. 48.—Illustrating the Grading of Colour Ranges to obviate reversing of Pattern.

so that in every colour scheme the two features, colour and luminosity, are really brought into play.

From the practical point of view the first consideration should be the fastness of the colours selected to finishing and ordinary wearing conditions. The organization of graded ranges of shades and tints of correct tones and intensities is the next important factor. This will best be effected by basing the ranges selected upon the tints, shades and tones of the spectrum colours. It is not necessary that a complete range of spectrum colours shall be represented. If, for instance, greens are fashionable, the green tints, shades and tones may at least predominate in the selection, and so on according to the prevalent taste in colour. In order that the reversing illustrated in Fig. 47 may be avoided it is very desirable that the ranges of shades should be organized upon the lines illustrated in Fig. 48, from which it will be gathered that so long as the designer takes, say, his ground colours from the same grade of darks and his checking colours from the same grade of lights the reversing of the pattern illustrated in Fig. 47 will be impossible, and hence the spoiling of, say, a range of eight patterns by one of the eight being accidentally reversed will be avoided.

By some such organization of colours as this the designer will find that not only can he do with about half the shades he would otherwise require, but he will also find that his ranges of colours actually inspire him to design. Some of the French pattern firms supply magnificent ranges of colours which the textile designer should always have by him, as such, even if not of direct use, tend to guide one into good methods, and good method in textile design and

colouring results in economical production without any real suppression of the artistic feeling and instinct of the designer.

Figure Designing.—This involves a two-fold qualification, viz., the qualification of the artist to create artistic forms and patterns, and the qualification of the cloth constructor not only to render in the fabric the patterns designed, but rather to qualify the artistic qualification so that the limits of textile design may be taken as an inspiration rather than as a limitation.

Brief consideration of the fact that woven fabrics are composed of threads at right angles to one another will result in the limits of textile design being fully realized.

In designing for figures any of the structures mentioned on p. 178 may be employed; but as a rule the designer will be given a typical foundation fabric to design to. The usual limit for the Lancashire and Huddersfield design is about 400 threads, *i.e.*, a cloth 100 threads per inch, about a 4-inch pattern. Bradford, however, largely employs a jacquard figuring with 300 threads, while Belfast and some of the silk and tapestry districts figure up to 1,200 or 1,800 threads by any required number of picks.

CHAPTER IX

THE PRINCIPLES OF FINISHING

Most fabrics are somewhat uncouth and unsatisfactory as taken from the loom. Some few, such as various silks and a few cotton styles, are not markedly changed by the subsequent finishing; others, such as woollen fabrics, are so changed that it is difficult to believe that the harsh, unsightly fabric taken from the loom can be so changed—so improved—by a few simple finishing operations.

Finishing may be varied in three marked ways. Firstly, it may be applied with the idea of making the best of what is present in the cloth under treatment without the addition of any so-called finishing agents; secondly, it may principally consist of adding a finishing agent or "filler" to the fabric, the fabric being merely a foundation to hold the "filler" together; and thirdly, a combination of the two foregoing ideas is possible in which the nature of the fabric is suitably fortified with a not undue allowance of some suitable "filling" agent.

In the first class come most wool fabrics, in which the nature of the wool is, or should be, fully developed by suitable spinning and twisting, suitable weave structure and suitable finishing. The perfect wool texture is only producible by full deference being paid to all these factors. But even in the various all-wool goods a marked difference

is observable. The typical woollen cloth is a cloth made in the finishing. The typical worsted cloth is a cloth made in the loom. But between these extremes there is every grade imaginable, from the worsted-serge or vicuna of worsted warp and woollen weft, with a pure woollen finish, to the typical West of England woollen with almost a worsted finish.

In the second class come certain cheap calicoes, and of late certain cheap silks, with a very large percentage of filling. Little exception can be taken to the calicoes. They are sold for what they are, and no one is taken in. With the silks, however, it is quite otherwise. The goods in question are sold as silks, and no reference is made to the percentage of filling, which is sometimes truly astounding. Sometimes the silk spinner or manufacturer imposes upon himself. For example, a silk spinner gives instructions for his yarns to be dyed and loaded up say 40 per cent. Now this yarn in discharging may lose 30 per cent.; so that if the spinner gets back for every 100 lbs. of grey yarn 140 lbs. of dyed yarn, the proportion of filling to silk is—As 70 : 70 or 100 per cent., although it may only be stated at 40 per cent. The ease with which silk can be loaded or filled has enabled unscrupulous silk merchants to take in an all too trusting public. The filling of silk goods has been carried on to such an excess that at the present moment there is a strong reaction against it.

In the third class come some few wool goods and a large variety of cotton, linen and silk goods. Few wool goods can be improved with any filling agent. Meltons and heavy milled cloths may perhaps be improved by a stiffening agent in their interior, and the necessary weight, but no

extra value, may be added to worsted coatings by such a weighting agent as chloride of zinc. These, however, may be taken to be the exceptions which prove the rule. Most cotton goods are improved and rendered more sightly by either adding filling or by smoothing down the size already present in the warp yarn. Linen goods specially lend themselves to, one might almost say, "showing-off" a filling agent "starch"—in fact, it is quite questionable whether the goods should not be placed in the second class. Some certainly should; others are not abnormally "filled." Silks, being frequently woven in the "gum," must be discharged in finishing; but it is probable that the presence of a small amount of silk gum in the bath and on the fibre is necessary to preserve the best characteristics of the texture under treatment.

Finishing Processes and Machines.—As many processes and machines are common to all the recognised fabrics, such may be described generally prior to a particular description of the finishing operations necessary for representative fabrics.

Mending, Knotting and Burling.—This consists in repairing the broken threads and picks nearly always present in the fabric as it leaves the loom. It is also advisable to mend pure worsteds after scouring, as the faults are then more easily seen. The mending wage for fine worsteds is frequently equal to the weaving wage. Knotting and burling are also carried out at this stage.

Scouring.—This consists in thoroughly cleansing the fabric prior to proceeding with the finishing proper. Certain cotton, cotton and wool, and silk cloths are so clean on leaving the loom that the finishing proper is at once

proceeded with. Many wool goods, however, must be scoured fairly clean in what is known as the "dolly" or on the five-hole machine, before they will satisfactorily take the finish for which they are designed. Again, colours running in the scouring may often be scoured out, while if left in for the milling they will truly "bleed" and permanently stain the neighbouring threads and picks.

Milling.—This operation is equivalent to hammering or squeezing the cloth until it has attained to a sufficient solidity. Wool only of all the textile fibres "felts," as it is termed, so that this operation is practically limited to wool or wool combination goods.

Two machines are employed to effect the required felting, yielding somewhat different results. The milling stocks, imitating the original treading action of the human feet, hammer the cloth (which is placed in a holder or receptacle so shaped that the falling of the hammer not only "mills" or "felts" but also turns the cloth round so that its action is evenly distributed over all its surface). The action of the stocks is obviously of a bursting nature, giving "cover" on the fabric.

The "milling machine" works on the squeezing basis, the cloth to be milled being squeezed up in lengths or in width or both according to requirements. This machine not only gives a more solid cloth, but also enables the miller to control the width and length and consequently the weight per yard.

Crabbing.—This is an operation based upon the fixing qualities of wet heat as applied to various textures, and upon the desirableness of the first shrinking and consequent setting of the fabric being very carefully controlled. The

fabric to be "crabbed" is wound dry and perfectly level on to a roller and then under tension wound on to a roller running in hot water. From this roller the fabric may be run to another roller under similar conditions. There are various forms of crabbing machines, but the factors are always the same—wet heat and tension and weight.

A very useful but somewhat dangerous machine is used for finishing certain cotton warp and wool weft goods, consisting of four or five rollers running in scouring and washing-off liquors, round which the fabric is passed, followed by a series of drying rollers, so that the fabric in a sense is continuously scoured, crabbed and dried. This machine is dangerous in that "crimps" are not eliminated as in the case of true crabbing. Of course this machine may be employed in conjunction with the crabbing machine when the above objection does not hold.

A special crabbing machine employed in the woollen and worsted trade simply arranges for steaming while the fabric is being wound on to a true steaming roller upon which the fabric may be steamed and cooled off; or it may be wound on to a roller for "boiling" if necessary.

Steaming.—If the fabric is to be steamed it is run from the last crabbing roller on to the steaming roller—a hollow roller with a large number of holes pierced from its central tube to its periphery—so that steam may be blown right through the piece. The piece is usually re-wound inside out and re-steamed to ensure level treatment. It is then allowed to "cool off." The basis of this treatment appears to be a "setting" action, owing to the great heat employed no doubt partially dissolving or liquefying certain of the

constituents of the wool fibre. Prolonged steaming undoubtedly weakens wool fibres.

Dyeing.—From a mechanical point of view dyeing may be conducted on either the "open width" or "rope" method. Cotton goods, for example, must be piece dyed on the "jigger" full width if level shades are to be obtained, while wool goods are usually satisfactorily dyed in rope form. There is no satisfactory theory for this, but practically as fact it is a most important matter. Mercerized cotton has such an affinity for dyes that the utmost difficulty is experienced in finding a restrainer to effect the even distribution of the dye in light shades. Without some restraining influence the first few yards might take up the whole of the colouring matter.

Most goods must be opened out after dyeing, as if allowed to cool in a creased state they retain their creases. The point here to note is that to take out a crease it requires a greater heat than the heat at which the crease was put into the piece.

Washing-off.—This is a simple operation to ensure that all the unfixed colouring matters, etc., are cleaned out of the piece. As the action is mechanical, cold water may be employed.

Drying.—This is usually effected by passing the fabric round a series of steam-heated rollers. Owing to the way in which the fabric is wrapped round these rollers it never rests for long upon one roller, so that it cannot be burnt; again it is wrapped alternately face and back upon the rollers, so that it is really dried in the shortest possible time. In goods which may be worked by a straight pull on the warp either horizontally or vertically arranged drying

rollers are ample; but if any extension in width is desired a tentering machine must be employed. As previously explained, these drying rollers are usually arranged in conjunction with another operation—say, continuous scouring and crabbing. Of late there has been a most marked tendency to hot-air dry.

Tentering.—This consists in holding the cloth tightly in the warp direction and widening it in the weft direction. To effect this the cloth is pinned by hand on to two continuous tenter chains, which as they carry the cloth into the machine gradually increase the distance between them, thus tentering out the cloth. The "give" of the cloth is probably due to three factors, viz., give in the fabric structure, in the thread structure, and in the fibre itself. Obviously, unless the cloth is "set" in this position it will more or less shrink after the process. To effect the setting the cloth must be fed into the machine damp; in this condition it must be widened or straightened out, and then in the widened out condition it must be dried. In the most approved tentering machines the expanding chains carry the fabric over gas jets which just supply the necessary heat for drying. A steam-jet pipe is also provided to damp the cloth just prior to or during tentering to give it the necessary plasticity. In the enclosed "steam-pipe" type of machine the efficiency of the machine is often impaired by the difficulty of getting away the hot moisture-charged air, but as drying largely depends upon this and not so much upon the heat developed, this must be done if efficient and economical working is to be attained.

It will be evident that goods "tentering out" will have a tendency to shrink. London tailors are credited with

always testing the natural shrinkage of these goods by folding them with a thoroughly wetted and wrung out cloth for a day or two, and then noticing the shrinkage which has taken place. Goods so treated are spoken of as "London shrunk."

Brushing and Raising.—After scouring, milling, etc., most wool goods and some few others present a very irregular face, neither clear nor yet fibrous. If a clear face is desired the few fibres on the face must be raised as much as possible in order that they may be cropped off in the cropping or cutting operation which follows. To effect this the face of the fabric is regularly presented to the action of a circular brush or to the action of "teazles."

Should a fibrous face be desired—technically termed a "velvet" face—the fabric must be raised wet on what is termed the "raising gig" from head to tail, from tail to head, and across if possible, to obtain a sufficiently dense fibre, naturally somewhat irregular in length.

The "raising gig" proper carries teazles, which without damage to the foundation of the fabrics submitted to them raise a sufficiently dense pile. For flannelettes and some other goods a stronger machine is required; in this case wire teeth, specially constructed and specially applied, take the place of the teazles. Teazles themselves vary much in raising qualities; and the experienced raiser knows this and takes advantage of it.

Cropping or Cutting.—To obtain a perfectly level face on fabrics they must be submitted to a "cropping" or "cutting" operation. Formerly cropping was more or less efficiently done with large shears, but to-day much better and more accurate work is done by the circular

"cropper," which, working on the principle of the lawn-mower, may be set to leave a pile of any required length, or if desirable to practically leave the fabric bare. The cutting action is due to the combined action of the fixed bed and the spirally arranged revolving blades.

Singeing.—Some fabrics, such as Alpacas, Mohairs, etc., are required to have a clear lustrous face such as no cropping machine can possibly leave. Singeing must here be resorted to. The fabric to be singed is quickly passed face downwards over a semi-circular copper bar heated to almost white heat. The speed of the cloth naturally decides to a nicety the amount of singeing effected, but to avoid damage to the fabric a quick speed is usually adopted and the fabric passed over, say, six times. Gas singeing is not extensively applied save in genapping, *i.e.*, singeing and clearing braid, etc., yarns.

Pressing.—By means of the hydraulic press great weight may be put on to fabrics, and they may thus be more or less permanently consolidated and in some cases lustred. Heat may be applied in the press, thus aiding in the fixing of the fabrics under treatment.

Presses are practically made in three forms: ordinary, intermittent, and continuous. The ordinary press simply receives its charge of cloths in the ordinary cuttled form, heat being introduced through the expanding or contracting press-plates separating individual pieces. Press papers are placed between the cuttles of the pieces to form the surface against which the fabric is pressed.

In the intermittent form about five yards is treated at once, suitably pressed and held stationary in the heated machine for, say, a minute, and then automatically moved

on so that the ensuing section of the fabric may be treated in like manner.

In the continuous form the pressing is continuously effected.

The time factor naturally varies in all three forms, and is naturally the factor which decides which is the most efficient machine for particular classes of goods.

Calendering.—This operation simply consists in passing goods through heavily weighted and if desirable heated rollers which it is found break or render less "caky" fabrics passed through them. The probable action is to distribute rigidity or solidity.

Schreinering.—This operation consists in passing suitably constructed cloths between a pair of solid heavily weighted steel rollers, one of which has a plain papier-mâché surface and the other is ruled with extremely fine lines from 190 to 500 to the inch. The effect on the piece is to develop a really wonderful lustre specially applicable to mercerised cotton goods.

Filling.—As already remarked, it may be desirable or necessary to stiffen some goods to increase their utility. Again, some goods are "filled" simply to attain a desired weight.

Soap or other agents may be cracked in pieces or the pieces may be definitely impregnated with some such agent as chloride of zinc. It is hardly necessary to add again that filling is rarely legitimate.

Conditioning.—After fabrics have passed through a process involving the application of dry heat—such as singeing—they are unnaturally dry, and as a consequence are very weak. To give back the natural moisture, goods in such a

condition are passed through a machine which "sprays" them and thus causes the fabric to quickly regain the moisture and often the strength lost.

The foregoing are the principal operations in finishing. The secondary operation such as hydro-extracting, burl-dyeing, extracting, etc., are of such minor importance that there is no need to specially refer to them here.

Waterproofing.—Fabrics may be rendered water-proof in three distinct ways. Firstly, the fibres of which they are composed may be rendered moisture-repellent, as, for instance when wool is subjected to the action of super-heated steam. Secondly, the fibres may be charged with a water-repellent substance, which thus prevents the passage of water save under pressure. Oiled fibres, for instance, possess this characteristic. In these two cases the surface tension of the liquid which endeavours to pass through the fabric plays an important part. Thirdly, the fabric may be "plastered" or entirely coated with some such agent as india-rubber.

All three methods are employed, and there are, of course, combinations which are not precisely one or the other.

General Notes.—To give an idea of how the foregoing operations are applied in finishing specific types of fabrics the six following lists are given :—

Woollen Cloth. (All Wool.)	Worsted Cloth. (All Wool.)	Lining Fabric. (Cotton and Wool.)
Mending, Burling, etc.	Mending, Burling, etc.	Mending.
Soaping.	Crabbing.	Crabbing.
Scouring.	Soaping.	Steaming and Setting.
Milling (Stocks).	Scouring.	Dyeing.
Milling (Machine).	Mending.	Washing-off.
Washing-off.	Light-milling.	Tentering and Drying.
Hydro-extracting.	Washing-off.	Singeing (several times).

Woollen Cloth.
(All Wool.)

Crabbing.
Tentering and Drying.
Brushing and Dewing.
Raising.
Cropping.
Brushing and Steaming.
Cutting.
Pressing.
Steaming.
Cuttling.

Worsted Cloth.
(All Wool.)

Hydro-extracting.
Crabbing.
Tentering and Drying.
Dewing or Conditioning.
Brushing and Raising.
Cropping.
Brushing.
Dry Steam Blowing.
Cuttling, Rigging.
Folding and Measuring.
Pressing.

Lining Fabric.
(Cotton and Wool.)

Washing-off or Conditioning.
Tentering.
Pressing.

Silk Fabric.[1]
(Net Silk.)

Singeing or Cropping.
Discharging and Washing.
Drying.
Cylindering.
Damping, or Dressing and Singeing.
Calendering and Lustring.
Rolling or Plaiting.
Pressing.

Cotton Fabric.[1]
(Calico.)

Singeing.
Souring.
Washing.
Saturating with Caustic Soda.
Kier Boiling.
Washing.
Chemicing.
Washing.
Souring.
Washing.
Squeezing.
Mangling.
Drying.
Filling.
Drying.
Damping.
Stretching.
Beetling or Calendering.
Making-up.

Linen Fabric.[1]
(Standard Style.)

Lime-boiling.
Washing.
Souring.
Washing.
1st Lyre boil.
Washing.
Chemicing.
Washing.
Souring.
Washing.
2nd Lyre boil.
Washing.
Grassing.
Chemicing.
Washing.
Souring.
Washing.
Scalding.[2]
Washing.[2]
Chemicing.[2]
Washing.[2]
Souring.[2]
Washing.[2]
Scutching.
Water-mangling.
Starching and blueing.
Beetling.
Breadthening.
Calendering.
Lapping.

[1] These details are supplied by specialists in the respective branches of the industry. All are preceded by operations equivalent to Mending, Burling, etc.

[2] These processes must be varied in accordance with particular requirements.

The foregoing lists seem fairly comprehensive, but in reality they by no means convey a complete idea of the many different styles of finish. For woollen cloths, for example, some half-dozen typical and distinct finishes could be cited, and the other styles are by no means without their varieties (see Fig. 53F).

There can be no doubt but that more attention to the effects of "finish" is much to be desired. To thoroughly demonstrate the influence of each specific process the best method is to pass a suitable length of fabric through the necessary or desirable operations, and to cut off, say, a yard length from the fabric after each operation as a reference. Thus for a piece-dyed Botany coating reference lengths should be preserved of (*a*) warp and weft; (*b*) grey cloth; (*c*) scoured cloth; (*d*) milled cloth; (*e*) dyed and tentered cloth; (*f*) raised cloth; (*g*) cut cloth; (*h*) steamed cloth; and (*i*) pressed cloth. The record of all the foregoing reference samples should include (1) counts of warp and weft; (2) threads and picks per inch; (3) length and width; (4) weight; and (5) strength. Such records as these have been worked out in the Testing Laboratories of the Bradford Technical College during the past six to eight years, and are found to add most markedly to the efficiency, value and interest of the investigations undertaken.

CHAPTER X

TEXTILE CALCULATIONS

In a general sense most textile calculations have, and should have, reference to the ultimate cloth produced. It is true that there is a distinct "wool" trade, a distinct "top" trade, and a distinct "yarn" trade, each of which is in a sense independent of the cloth trade. It is nevertheless obvious that all nomenclature, designation and indication should be on some basis readily understood and easily applied by the cloth constructor.

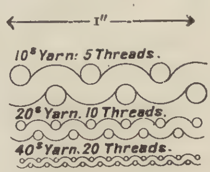


Fig. 49.—Illustrating the Setting of Fabrics; also the Weights of Fabrics.

Unfortunately the "science of cloth construction" was developed so late that not one but many cumbersome methods had long been firmly established, so that to-day a considerable portion of the designer's and cloth-coster's time is wasted on calculations which, with full cognisance of all possible conditions, might easily have been eliminated by the adoption of convenient standard systems for counts of yarn, sets, etc.

Starting from the cloth it is evident that the most useful designation for yarns would be in fractions of the inch (or of a decimeter). Thus 1's yarn would have a diameter of 1 inch, 2's of $\frac{1}{2}$ inch, 3's of $\frac{1}{3}$ inch, 4's of $\frac{1}{4}$ inch, and so on,

or that 1, 2, 3, 4, etc., threads might be laid side by side in an inch. The "set" calculations for cloths on this basis would be very simple. On this basis, as shown in Fig. 49, with plain weave, a 10's yarn would be set five threads per inch, a 20's yarn ten threads per inch, and a 40's yarn twenty threads per inch. Moreover, on this system, the weight of the cloth would vary in inverse proportion to the counts, for, as shown, the cloth with 20's count is half the thickness or weight of the cloth with the 10's count, the cloth with 40's count is half the weight of the cloth with 20's count, and *vice versâ.* If the 10's count cloth was a 30 oz. cloth, the 20's count cloth would be a 15 oz. cloth, and so on. Again, the "sets" or threads per inch and picks per inch for any given weave or interlacing would be simplicity itself. As shown in Fig. 50, for example, the threads and picks per inch would be—

$$\frac{\text{Counts of yarn} \times \text{threads in repeat of weave.}^{1}}{\text{Threads} + \text{intersections in repeat of weave.}}$$

Thus with a 60's yarn in $\frac{2}{\quad}{}_{2}$ twill the set should be—

$$\frac{60 \times 4}{6} = 40 \text{ threads and picks per inch.}$$

Of course the practical designer would slightly vary the set in accordance with the material he was using; if rough and slackly twisted he would probably put 38 threads per inch, while if smooth, compact and hand-twisted, he might put 42—44 threads and picks per inch. He would also probably take into account the effects of finish, and, of

[1] This is a fairly accurate approximation for ordinary fabrics in which warp and weft bend equally. Note that it is only applicable in this form if count equals the diameter of the yarn.

course, the handle of the ultimate texture he hoped to produce.

Unfortunately this simple system is quite out of count, firstly, because yarn counts designate length and not diameter; and secondly, because yarn and set numbers vary in different localities.

Undoubtedly in the early days of the textile industry yarns were spun very irregularly and to unknown counts in any and every denomination. Then the idea of spinning a definite weight of wool, say 6 lbs., to a given length of yarn, so that a given length of piece could be got out of it, would impress itself upon the more thoughtful spinners. Thus the Leeds "wartern" is 6 lbs., and if the yarn was spun to 1,536 yards, or 1 yard per dram, it was called 1's count, if to 2 yards per dram, 2's count, and so on. In most localities, however, the unit of 1 lb. would be naturally adopted as the weight. Unfortunately there was not the same unanimity with reference to the length. To number 1 yard to 1 lb. 1's count, 2 yards to 1 lb. 2's count, 20 yards to 1 lb. 20's count would be out of the question, as a very thick yarn would then have 256 as its number, and a fine yarn, say, 2,560 as its number. To reduce this count number to thinkable and workable

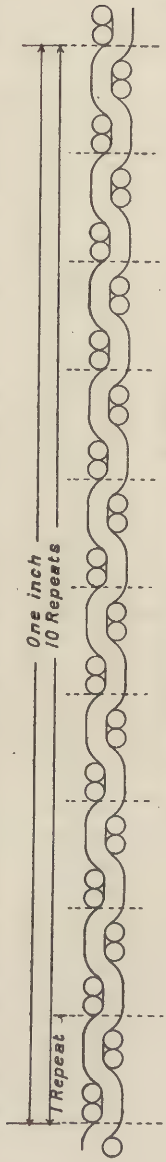


FIG. 50.—Illustrating the Setting of Fabrics.

proportions, in some cases the weight was reduced,[1] and in others the system of "hanking" was resorted to. But the localized character of the various industries unfortunately resulted in a varying weight and a varying number of yards per hank being adopted. In most count systems the hanks per lb. (avoirdupois) indicate the count. Thus 20's count equals 20 hanks per lb., 30's count equals 30 hanks per lb., and so on. But the cotton hank is

List IX.—Various Systems of Counting Yarns.[2]

Length constant. Weight variable.

System.	Weight.	Length of Hank.	Yards per hank × count, × by gauge point = yards per lb.
Cotton . . .	1 lb.	840 yards	× 1
Worsted . . .	1 lb.	560 yards	× 1
Linen and Hemp .	1 lb.	300 yards	× 1
Raw Silk . . .	1 oz.	Number of yards	× 16
Dewsbury . .	1 oz.	Number of yards	× 16
Yorkshire Skeins Woollen . .	6 lbs.	1,536 yards	× ·16
Galashiels . .	24 oz.	300 yards	× ·66
Hawick . . .	26 oz.	300 yards	× ·61
Stirling and Alloa .	24 lbs.	Cuts Yds. 48 × 240 (Spindle)	× ·04
West of England .	1 lb.	320 yards	× 1
German wool count .	½ kilog.	2,200 Berlin ells	
Run (American) .	1 oz.	100 yards	× 16
Cut (American) .	1 lb.	300 yards	× 1
Metric . . .	1 kilog.	1,000 metres	× ·45
French Metric . .	½ kilog.	1,000 metres	× ·9

[1] The Yorkshire system may be said to be based upon the yards per dram, and there is also a system based upon yards per ounce, and 1,000 yards per ounce.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

840 yards;[1] the worsted, 560 yards; the linen, 300 yards; Yorkshire woollen skein, 256 yards; West of England, 420 yards; and Galashiels, 300 yards for 24 oz.; so that further complexity has thus been introduced. With the table accompanying, however, the yards per lb. in any denomination may readily be found, and from the yards per lb. any weight or diameter calculation readily worked out.

LIST IXA.—VARIOUS SYSTEMS OF COUNTING YARNS.[2]

Length constant. Weight variable.

System.	Unit of Length.	Unit of Weight.	Count.
Halifax Rural District	80 yards	Dram	Repeats of unit weight in unit length = the counts.
Jute, Heavy Flaxes and Hemp	Cuts Yds. 48 × 300 (Spindle)	lb.	
Denier System . .	Raw silk (476 metres or 520 yards)	Denier	
Dram System . .	1,000 yards	Dram	
International Denier .	500 metres	½ decigramme	
Legal Silk count appd. in Paris, 1900	450 metres	½ decigramme	
American Grain .	20 yards	Grain	

Curious to relate, the √ of the yards per lb. of any material (with a suitable allowance of from 5 to 15 per cent.)

[1] No doubt originating from a reel of a convenient circumference, with a convenient number of warps upon it.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

gives the approximate working diameter of any yarn. Working backwards diameter ^{2} = the area of a square, and the area of a square varies inversely to length; therefore the diameter varies inversely as the $\sqrt{}$ of the length, and as count of yarn is in proportion to length therefore *the diameter of a yarn varies inversely as the $\sqrt{}$ of the counts* (that is denomination being the same).

This accounts for the relationship of diameter of yarn and lengths or counts, but not for the $\sqrt{}$ of the yards per lb. being the actual numerical diameter in fractions of an inch. This coincidence suggests that there is some method in the madness of the English lb., yard and inch, and that they are not merely haphazard standards. If the metric count system is adopted the $\sqrt{}$ metres per kilogram $\times$ 2·4 = the threads per decimeter, the decimeter being the most convenient unit to adopt for sets.

The most important systems of counting yarns with length constant and weight variable are given in List IXA.

In the foregoing particulars the inch is taken as the basis. Unfortunately the inch has been taken as the basis in very few manufacturing districts. The reason for this is not far to seek. Bradford, for instance, apparently based its set particulars upon the yard, Leeds upon the $\frac{1}{4}$ yard or 9 inches; Blackburn upon $1\frac{1}{4}$ yards; while possibly other districts, owing to French and Flemish immigration, based their sets upon the Flemish ell or French aune—$\frac{3}{4}$ yards or 27 inches—which later possibly being converted into terms of the yard, would create further confusion.

But this is not all. It was evidently found convenient to

warp with a given number of threads. In Leeds thirty-eight (termed a "porty") were employed; in Bradford forty (termed a "beer"), and so on. Thus it became customary for the set of a fabric to be defined by the number of times the threads warped with repeated in the standard width. Thus the Leeds "set" is the "porties per quarter (9 inches)," the Bradford set the "beers per 36 inches or one yard." So little impregnated with scientific method are the textile industries even to this day that these very local standards are still in full use. Thus the man who speaks of threads per inch in Bradford or Leeds mills speaks in an unknown tongue, and is not in the least understood. Of course there is a tendency to reduce these sets to the threads per inch standard. Thus the Bradford man sometimes states the Bradford set as being based upon $1\frac{1}{9}$ threads per inch; but even he is an exception and usually there is not the slightest endeavour to make the inch the standard; in fact, there is antagonism of a somewhat violent character against any change.

The following are the principal set systems with their gauge points for finding the threads per inch (see List X., p. 212).

Some of the most difficult calculations and also some of the easiest possible calculations which the textile designer has to work out have reference to the weight per yard of the fabrics with which he deals. In the worsted coating and the woollen trade the weight per yard (usually 54 inches × 36 inches) is the basis of all dealings; in the stuff, cotton and other trades, although often stated, it is by no means so important. Now under simple conditions of yarns and

P 2

set there is no difficulty in calculating the weight of a piece. The calculation simply stands—

$$\frac{\text{Yards of yarn in piece}^{1}}{\text{Yards per lb. of yarn employed}} = \text{lbs. weight of piece,}$$

$$\text{and } \frac{\text{lbs. of cloth} \times 16}{\text{length of cloth in yards}} = \text{oz. per yard.}$$

List X.—Various Systems of Indicating the Set.

Locality and System.		Standard width in inches.	Number of Threads in one Beer, Portie, etc.	Given Set to find ends per inch.
Yorkshire	Bradford	36	40	× 1·11
	Leeds	9	38	× 4·22
	Huddersfield and U.S.A.	1	Splits per inch × ends in splits.	
	Dewsbury	90	38	× ·422
Lancashire	Bolton	$24\frac{1}{4}$	40	× 1·64
	Blackburn	45	40	× ·9
	Manchester	36	2	× ·055
	Stockport	2	2	× 1
Scotch	Glasgow	37	2	× ·054
	Tweed	37	40	× 1·08
Belfast and North of Ireland	Linen Plain, etc.	40	2	× ·05
	,, Damask	30	40	× 1·33
	,, ,,	37	2	× ·054
	,, ,,	Ends per inch × reed width.		
	Silk	Width of fabric, number of ends in each split.		

There are, however, a few complications likely to arise. Yarn counts may be in two or more denominations, threads of various counts or thicknesses may be twisted together

[1] This further extended is:

$$\frac{\text{Threads per inch} \times \text{width in loom} \times \text{yards long of warp}}{\text{Warp counts} \times \text{hanks per lb.}} +$$

$$\frac{\text{Picks per inch} \times \text{width in loom} \times \text{yards long of cloth}}{\text{Weft counts} \times \text{hanks per lb.}} = \text{lbs. of cloth,}$$

to form part or the whole of either warp or weft, warp and weft may be composed of several colours, there may be differences in shrinkage and loss in weight of warp and weft during finishing, and other disturbing influences of a less pronounced type. All the foregoing influences, with one exception, are either so easy of comprehension or are necessarily so dependent upon practical conditions that no attempt need be made to deal further with them here. The exception is the twisting together of yarns of varying thicknesses. For instance, what is the "count" of a 40's cotton twisted with a 40's cotton; a 30's cotton twisted with a 40's cotton, and a 30's cotton twisted with a 60's worsted?

There are really four methods of working out such problems as these.

1st Method.—Base the calculation upon a yard of each material being twisted together.

Thus the first calculation will stand—

$$\frac{1 \text{ lb.}}{40 \times 840} + \frac{1 \text{ lb.}}{40 \times 840} = \frac{1}{16,800} \text{ of 1 lb.; } i.e., \text{ 1 yd.} =$$

$$\frac{1}{16,800} \text{ of 1 lb.} \therefore \text{1 lb.} = 16,800 \text{ yards} = \frac{16,800}{840}$$

$= 20$'s cotton counts.

2nd Method.—Work upon the L. C. M. of the number, take this as the length in hanks and proceed as before.

Thus the second calculation will stand—

L. C. M. of 30 and 40 = 120 hanks as length for combination.

$$\frac{120}{\frac{120}{30} + \frac{120}{40}} = \text{hanks per lb.} = \text{counts.}$$

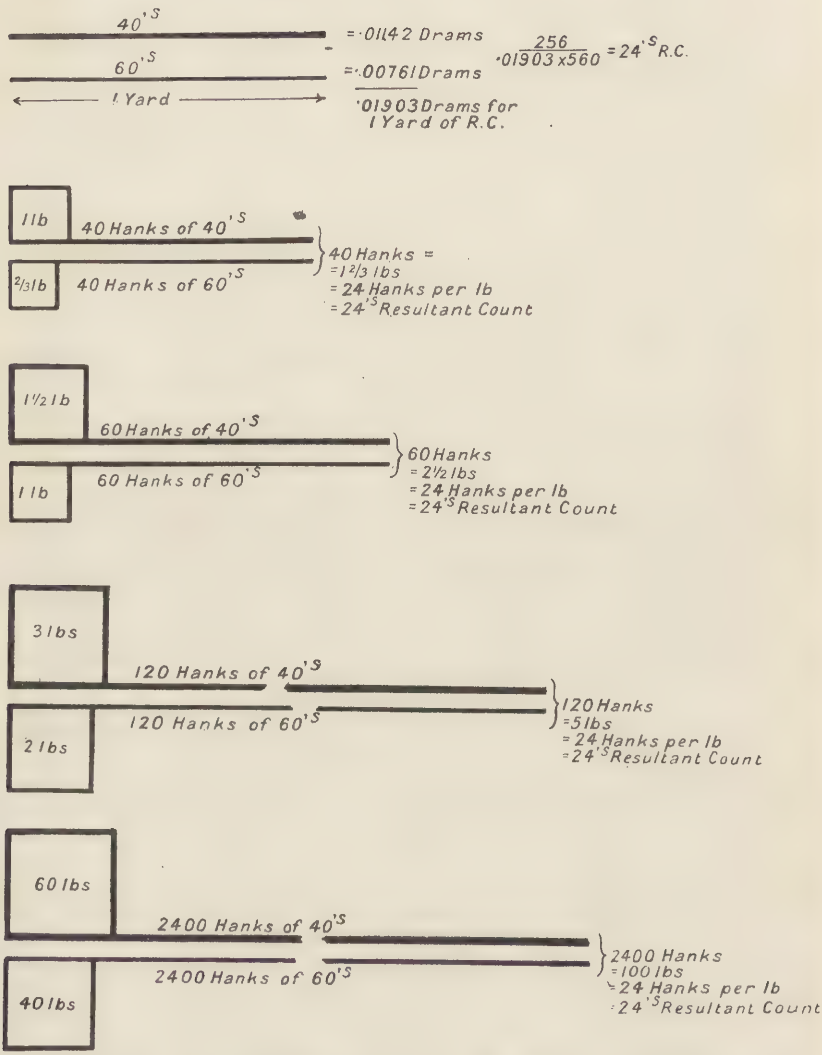


FIG. 51.—Graphic Illustration of the Resultant Counts of Twisting together two Threads of Different Counts.

This is better stated as follows—

Hanks.	lbs.
$120 \div 30 =$	4
$120 \div 40 =$	3

120 weighing 7 = 17 hanks per lb. or 17's counts.

3rd Method.—Work by means of the suitable, if somewhat large numbers, found by multiplying the two count numbers together.

Thus the third calculation will stand—

$$\left(60\text{'s worsted} = \frac{60 \times 2}{3} = 40\text{'s cotton}\right),$$

$$30 \times 40 = 1{,}200 \text{ hanks.}$$

$$\frac{1{,}200}{\frac{1{,}200}{30} + \frac{1{,}200}{40}} = \text{hanks per lb.} = \text{counts.}$$

The second method seems so much more covenient than the other two that it is most desirable to adopt it whenever possible. Its convenience is all the more marked when the prices of the yarns are given and the price per lb. of the resultant count is required; and again when three or more yarns are to be folded together. Such calculations are so simple in the light of the foregoing that it is not considered necessary to treat them further here (see graphic illustrations).

The changing of the weights of cloths presents one or two features which are somewhat curious and should be specially noted. For instance, to make cloths lighter—(*a*) Warp may be kept the same, and a thinner weft or fewer picks per inch of the same weft may be inserted; or if the cloth is

built on the square (*b*) the whole structure of the cloth may be changed and *more* threads and picks per inch may be inserted of a finer yarn. The explanation of this seemingly contradictory method is that to make a cloth lighter it must be made *thinner* (supposing that in the first place it is perfectly constructed), and to make it thinner a smaller *diameter* of yarn must be employed; and with a smaller diameter of yarn more threads per inch, in exact proportion to the decreased diameter of the yarn, must be inserted to maintain the balance of structure. Thus the cloth is lighter because more threads and picks per inch indirectly imply a thinner cloth. Similarly, to make a cloth heavier *fewer* threads and picks must be inserted (see Fig. 49, p. 205).

But these statements and facts are put in terms of the diameters of the yarns. To make it practical then—remembering that $\sqrt{}$ counts is in proportion to the diameter—the rule will be—change the $\sqrt{}$ counts of yarns inversely in proportion to the required change in weight, and change the threads per inch in proportion to the required weight change. An example will well illustrate this—

Example.—A cloth is woven of 2/32's cotton, set 60 threads and picks per inch and is required $\frac{1}{4}$ heavier.

$$\tfrac{4}{4} \text{ to become } \tfrac{5}{4}; \text{ proportion} = \text{as } 4:5.$$

As $5 : 4 :: \sqrt{16} : \sqrt{x}$ and $x = 10{\cdot}24$ counts of say 2/20's.

As $5 : 4$, or

As $\sqrt{16} : \sqrt{10{\cdot}24} :: 60 : x = 48$ threads and picks per inch.

Proof $\dfrac{60 \times 36 \times 1 \times 5}{16 \times 840 \times 4} = \dfrac{48 \times 36 \times 1}{10{\cdot}24 \times 840}.$

Another calculation of this type involves a change in weave as well as weight, but as no new principle is involved we refrain from giving it. The varieties of the foregoing calculations are unlimited, but practically all the principles involved have been touched upon; a little common sense and mathematical instinct will lead to a speedy solution of any and all.

The simplification of practical conditions to ensure speedy work may have claim to passing comment.

Example.—A dress cloth when finished contains 88 ends per inch, and 80 picks per inch, is 63 yards long, 48 inches wide, and weighs 14 ounces per yard. It has shrunk 10 per cent. in length, 12 per cent. in width, and lost $\frac{1}{7}$th of its original weight. Ascertain the threads and picks per inch in the loom, length of warp and width of piece as in the loom, weight of material in the grey, and the finished and grey counts of yarn employed.

WARP FINISHED.	WARP IN LOOM.
? Counts of yarn (worsted).	? Counts of yarn.
88 ends per inch.	? Ends per inch.
WEFT FINISHED.	WEFT IN LOOM.
? Counts of yarn.	? Counts of yarn.
80 picks per inch.	? Picks per inch.
Length of warp finished 63 yds.	Length of warp in loom, ?
Width of piece finished, 48 ins.	Width of piece in loom, ?
Weight per yd. finished, 14 oz.	Weight per yd. in loom, ?
$\frac{1}{7}$ loss of original weight.	

To clearly state the problem like this is almost to

answer it. For example, the ounces per yard in the loom stands—

14 oz. + $\frac{1}{7}$ of the original weight = 14 oz. + $\frac{1}{6}$ = 16·33 oz. = per yard in loom.

Again:

As 168 (88 + 80 ends and picks per inch) : 88 :: 14 : x = 7·3 oz. of warp, and $\frac{88 \times 48 \times 1 \times 16}{7{\cdot}3 \times 560}$ = 16·5's count (if worsted).

Should the manufacturer be engaged in the Continental or South American trade it may be very desirable that he should work in the Metric System. All the foregoing principles may be readily applied in the Metric System by conversion, or, better still, directly by means of the following particulars:—

Worsted counts	÷	·885	= Metric counts.
Metric counts	×	·885	= Worsted counts.
Cotton counts	÷	·59	= Metric counts.
Metric counts	×	·59	= Cotton counts.
Yorkshire skeins	÷	1·939	= Metric counts.
Metric counts	×	1·939	= Yorkshire skeins.
In dram silk 515	÷	counts	= Metric counts.
515 ÷ Metric counts			= Dram silk counts.

Threads or picks per inch × 3·9 = threads or picks per decimeter.

Threads or picks per decimeter ÷ 3·9 = threads or picks per inch.

Bradford set × 4·33 = threads per decimeter.

Threads per decimeter ÷ 4·33 = Bradford set.

Rule to find the threads per decimeter (*i.e.*, fraction of a decimeter occupied) for any metric counts of yarn:

$\sqrt{\text{Metres per kilogram}} \times 2{\cdot}3$ for woollen yarns.[1]

" " " $\times 2{\cdot}4$ for worsted yarns.

" " " $\times 2{\cdot}5$ for cotton yarns.

Rule to find the threads per decimeter for any ordinary weave:

$$\frac{\text{Diameter of yarn in decimeters} \times \text{Thread in repeat of weave}}{\text{Threads} + \text{Intersections in weave.}} = \text{Threads per decimeter.}$$

Example:—Find the threads per decimeter for 2/18's cross-bred yarn employing $\frac{2}{\overline{\quad}2}$ twill.

$$\sqrt{9 \times 1{,}000} \times 2{\cdot}4 = 233 \text{ and}$$

$$\frac{233 \times 4}{6} = 155 \text{ threads per decimeter.}$$

Spinning and Weaving Calculations.—In preparing, combing, and spinning, calculations referring to both the machines employed and the materials passing through these machines frequently occur. The mechanical calculations involved cannot be entered into here. Nearly all spinning calculations involve the principle of drivers and driven, and most weaving calculations involve the principles of leverage, but the application of these simple principles are so varied that no satisfactory treatment of them could be given in the space at our disposal.[2]

The calculations referring to weights of slivers in drawing

[1] The slight differences here are allowances for the relative bulkiness of the materials of which the respective yarns are composed.

[2] See the "Wool Year Book," "Woollen and Worsted Spinning," etc.

and spinning, however, should at least claim passing comment. The ultimate end of spinning is, as we have seen, to produce a strand or thread of a certain count, *i.e.*, of a certain number of yards per pound (this is the simplest denomination). Now, working backwards one would expect the slivers always to be stated and calculated in yards per lb., and if it were so there would be many simplifications of drawing and spinning calculations. But in practice it is found more convenient to reel for fairly fine slivers 40 or 80 yards, and for thick slivers 10 yards. Thus English tops are placed on the market 7 ozs. per 10 yards. Botany tops are placed on the market 4 to 5 ozs. per 10 yards. An English top (say 40's quality) is usually made up in a ball about 230 yards long and weighing about 10 lbs. A Botany top (say 60's quality) is usually made up in a ball about 144 yards long, weighing about 5 lbs. Irrespective of these perhaps unnecessary difficulties drafting calculations are comparatively simple, as a sliver loses in weight exactly in proportion to its extension or draft, and necessarily increases in weight in proportion to the doublings. Thus if 40 yards of a "top" weigh 240 drams, then with drafts 5, 6, 8, 8, 6, 9, 9 and doublings 6, 6, 4, 4, 3, 3, 2, 40 yards roving will weigh

$$\frac{240 \times 6 \times 6 \times 4 \times 4 \times 3 \times 3 \times 2}{5 \times 6 \times 8 \times 8 \times 6 \times 9 \times 9} = 2\tfrac{2}{3} \text{ drams.}$$ [1]

In calculating the drafts necessary to give a total draft a difficulty may occur owing to drafts multipling themselves. Consequently if, say, a total draft of 10,368 is required in seven operations, then logarithms or the slide rule must be

[1] See Buckley's "Worsted Overlookers' Hand-book," and "Woollen and Worsted Spinning," by Barker and Priestley.

resorted to, the $\sqrt{}$ of the total draft being the average draft which may now be varied slightly to suit particular operations. Thus a top weighing 280 drams per 40 yards has to be reduced to 7 drams per 40 yards, at seven operations, the doubling being 6, 6, 4, 4, 3, 3, 2.

$280 \div 7 = 40$ and log. of 40 =	1·602 [1]
log. of 6 =	0·778
,, ,, 6 =	0·778
,, ,, 4 =	0·602
,, ,, 4 =	0·602
,, ,, 3 =	0·477
,, ,, 3 =	0·477
,, ,, 2 =	0·301
	7)5·617
	·802, log. of.

Answer, = 6·3 draft required.

Another calculation often misunderstood is the following:—To find the number of spindles in any part of the drawing or on the spinning frame, to follow any box of the drawing. If the question involved is simply between two boxes, say A and B, immediately following one another, then the weight taken by one spindle head on B divided into the weight given out by all spindle heads on A will be the answer. But should the frames in question be separated by other frames, for example, should the spinning spindles to follow the four-spindle drawing-box be required, then, although the same principle of weight $\div$ weight obtains, in addition the relative thickness, or, in other words, lengths of the respective slivers must be taken into account.

Example:—A drawing-box A with 4-inch front rollers

[1] Log of draft required if there were no doublings.

making 60 revolutions per minute delivers 240 drams per minute. What number of spinning heads B will be required if the diameter of the back rollers is $1\frac{1}{2}$ inches, making 5 revolutions per minute and taking in 8 drams per minute?

If A delivers the same length that B consumes, then

240 inches = 240 drams per minute from A,

$240 \div 8 = 30$ heads or spindles on box B to follow box A.

But B only takes in $7\frac{1}{2}$ inches relative to A giving out 240 inches, so that

$240 \div 7\frac{1}{2} = 32$ times length of B is required to consume length delivered by A.

Thus the total heads or spindles on B to follow A will be compounded of the weight difference and the length difference—

$$30 \times 32 = 960 \text{ spindles.}$$

It will be evident from the foregoing that many most interesting calculations occur in the textile industries. The points involved in these calculations are ordinary mathematical, geometrical, and trigometrical principles, and special principles and variations involved by the conditions obtaining in the industry. Many of the calculations could be materially shortened by the adoption of either the standard inch and pound or the metre and the gramme.

The chief point which stands out, however, is the need for some universally intelligible system. If we in this country are not prepared to adopt our own standard of the inch and yard and the pound of 16 ozs., we must be prepared for the metric agitators to prevail—our weakness will be their strength.

CHAPTER XI

THE WOOLLEN INDUSTRY

The Wool Industry may be divided into four main classes, viz., the Woollen Industry, the Worsted Industry, the Stuff or Dress Goods and Lining Industry, and the Upholstery or Tapestry Industry. Each of these has several subdivisions: thus the woollen industry may be considered to include the felt industry, the blanket industry, and in part the hosiery trade; the worsted industry includes also a section of the hosiery trade, and in part the braid trade; while the stuff or dress goods and lining industry includes many varieties almost attaining to distinct classes. The fourth class includes all pile fabrics of an upholstery type, and carpets and tapestry fabrics of a complex character.

The word "woollen" originally referred to fabrics made of the best Continental wool spun on the spindle-draft system, simply woven, felted, and often highly finished. The old "doeskin" was a typical example of the woollen cloth, and the care and skill required for its production may be gauged by the fact that it frequently took six weeks to finish, and sold up to 30*s*. a yard broad width. The present-day army officers' cloths may also be taken as typical of what was understood by the term woollen "in the olden days." It also seems probable that cotton cloths made from yarn spun upon the spindle-draft system and woven

into more or less soft fabrics were sold as woollens. About the year 1813 the re-manufactured materials made their appearance, and very quickly "catching on" became incorporated into the woollen trade, so that to-day the legal definition of a woollen yarn may be taken—as a yarn composed of fibres of any class of materials which may be said to possess two ends, which just possesses the strength necessary to allow the shuttle to lay it in the shed. To-day woollen cloths partake too much of these last named characteristics. Verily our grandfathers would have wept aloud could they have foreseen the degradation which was to overtake their trade and calling. For they were proud of their goods and of their good name for honest dealing. It must not be supposed, however, that the introduction of the re-manufactured materials is entirely a retrograde step. It is surprising what sound goods the Dewsbury and Batley manufacturers can make from low-class raw materials, and we must not forget that thousands of the poorer classes are well clothed by this means who otherwise would have to go very meanly clad indeed. It is the passing of re-manufactured materials as pure wool which must be condemned.

The better class woollen trade is located in the West of England, Huddersfield, Scotland, and Ireland. In the latter country it is not concentrated, but rather distributed.

The medium class woollen trade is largely located in the Leeds district with branches westward into the dales of Yorkshire.

The low class woollen trade is located in the Dewsbury, Batley, and Colne Valley district. The Continental woollen trade is very dispersed. In France, Elbeuf and certain

small towns like Sedan in the north are the principal centres. In Germany M.-Gladbach, Cottbus, Forst and Werdau are the main centres for cheap goods for men's wear. Verviers, in Belgium, is the centre of a large woollen spinning district, the yarns produced being shipped to England by the ton. In the north of Italy and in Spain woollen and worsted manufacture is developing, while Austria has a textile industry all too little known and appreciated in this country.

The woollen centre in the United States of America is in the New England States, Philadelphia being the chief city involved.

The supplies of material for these branches of the woollen trade are derived as follows:—For the fine trade Australian, Cape, South American, and Continental fine wools and some few fine cross-breds and English wools are employed; for the medium trade coarser Australian, New Zealand, etc., cross-breds with slipe and skin wool, noils, etc.; and for the low trade shoddy, extract, mungo, etc., scribbled with cotton sweepings, etc., to hold the blend together, are largely employed.

The woollen firm is usually self-contained, *i.e.*, it takes in the raw material and delivers the finished cloth, and also often merchants it. There are a few spinners of woollen yarn who do not weave and finish, and the "Rag Grinders" or "Mungo and Shoddy Dealers" of Dewsbury, Batley, and Ossett, form a distinct class to themselves; but these are the exception, not the rule. Thus a woollen mill will, as a rule, include the following machines or sets of machines:—

Scouring Machines.

Drying Machines.

Willows Fearnaughts	Placed in the Blending-room.
Scribblers Intermediates Condensers	Forming sets of machines to prepare for a given number of spindles.

Mules—pitch and number of spindles to follow cards.
Ring Twisters.
Warping, Dressing, Sizing and Drying Mills, and Machines.
Looms to follow the spinning.
Soaping Machines.
Dollies.
Hydro-Extractor.
Milling Machines.
Stocks.
Crabbing Machines.
Steam-Blowing Machines.
Tentering Machines.
Raising and Brushing Machines.
Cropping Machines.
Presses.

Few mills possess complete sets of scouring bowls—say four or five bowls to the set—as the materials they employ are of such a varied character and comparatively so small in bulk that it pays better to buy bulk lots scoured and to keep a single machine for dealing with the greasy lots. For the same reason the space over the boilers is usually plated as a drying house, although of course the best firms employ drying machines of an approved type, which yield the wool up in a nicely open and dried condition.

The willow is a very rough strong kind of card, which practically tears up and dusts the material, a fan and chimney being connected with it. The fearnaught is a nearer approach to the card, still more finely working the wool and ejecting it as a rule by means of an air blast.

Materials to be blended together are first passed through these machines, then built into a stack, layer by layer, and oiled at the same time, then beaten down with sticks and again passed through the fearnaught. The blend is then allowed to mellow before being passed on to the carding-room. The scribbler card to which the material is subjected opens it out lightly, the intermediate card treats it more severely, while the condensing card ensures a regular film of wool and then divides this film up into a number—say 120 films in 72 inches—of small slivers—count according to count to be ultimately spun to—which are wound on to the condensing bobbin ready for being passed on to the mule. On the mule these condensed slivers are at one operation drafted out to the counts required and twisted, or, if this would be too severe, they are first roved and then finally spun to the required counts. The following particulars respecting the relationships of the cards and mule spindles are useful and interesting (see p. 228).

The operation following spinning and twisting is warping if the yarn is intended for warp. If the yarn is intended for weft it will have been spun directly on to spools fitting the power-loom shuttles ; if for warp, on to cops holding a large quantity, and, if possible, a definite length of yarn to avoid waste in "bits." Warping is best effected on the Scotch warping mill, although the cheese system has by no means fallen into disuse. Upon whatever system the warp

SETS OF WOOLLEN MACHINERY FOR—

Coarse Work.	*Fine Work.*
Scouring.	Scouring.
Drying	Drying
(Carbonizing).	(Carbonizing).
1 Willow.	1 Willow.
1 Fearnaught.	1 Fearnaught.
Blending Process :—	Blending Process :—
1 treble scribbler—breast and 3 swift, Scotch intermediate feed.	1 double scribbler—breast and 2 swifts.
1 double carding engine—breast and 2 swifts, double-doffer condenser.	1 intermediate—breast and 1 swift, creel intermediate feed.
1 mule of 400 spindles.	1 double carding engine—breast and 2 swifts, tape condenser.
1 ring-twisting frame of 100 spindles.	2 mules, 600 spindles each.
	1 ring-twisting frame of 200 spindles.

is made a regular tension should be placed upon all the threads; if of a coloured pattern, they must be in their correct order; the right length should be accurately obtained, and the correct width for dressing on to the loom beam. Sizing follows, the idea here being to add a certain amount of strength to the yarn and to glue down the strong fibres and so ensure clear weaving conditions. Dressing and twisting follow, and then the warp is mounted in the loom. The favourite loom among woollen manufacturers now is the Dobcross, running at from 80 to 105 picks per minute. Several other firms also make woollen looms of an approved description. It is here interesting to note that in the woollen loom speed does not necessarily mean production, for woollen warps are frequently so tender that running at 80 picks per minute produces more cloth than running at 105 picks per minute. Of course for the cotton warps largely used in the low woollen and flannel trades

much quicker looms may be employed, 110 to 120 picks per minute being frequently attained.

As the woollen fabric leaves the loom it is unsightly, rough, and uncouth. But finishing changes all this. Scouring clears off the size, and, if skilfully done, also clears and develops the colours. Milling bursts the thread and gives a full-looking texture; tentering levels the piece, taking out all creases; crabbing fixes and gives lustre to the piece; raising brings a pile on to the surface; cropping levels it; steaming fixes; and wet-raising, boiling, etc., give a finely-developed permanent lustre.

The following example illustrates how all the processes in woollen manufacture must be applied with a definite idea of attaining a particular type of finished fabric:—A Melton cloth is required in which the finished fabric shows little or no trace of threadiness, but is of a felt-like appearance. To begin with, a good, fairly short, felting wool is required; this should be worked with as little drafting as possible, *i.e.*, condensed fine and spun without roving. The warp and weft yarns should be spun with inverse amounts of twist-in and in the same direction, say, open-band. The twill of the weave, should a twill be employed, should run with the twine of the yarn, so that warp and weft "bed" into one another as much as possible. The fabric must not be too closely set, as the fibres must be given room to take a "finish." The thread structure must be cleared in the scouring, broken in the stocks, and consolidated in the milling machine. The surface fibres must be raised up by dry-raising and closely cropped off to leave a bare clear surface without pile. Should stiffening be necessary, this may be effected by washing off the soaped

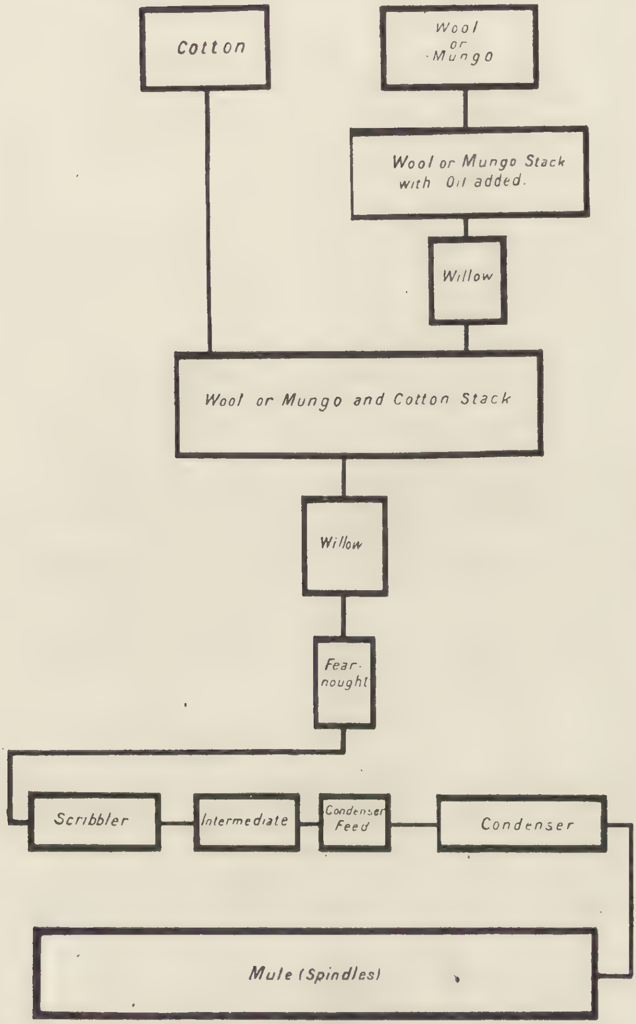


FIG. 52.—Graphic Illustration of the Order of Processes in Woollen Manufacture.

piece with hard water or by adding the necessary stiffening agents. Needless to say, the better piece will be that which requires no stiffening agent. Should the fabric come out of the press too highly glazed, it should be re-steamed to give it the requisite clear but somewhat opaque Melton finish.

Every distinct style of woollen fabric requires special attention in the finishing, as it is the finishing operations which make or mar the piece. A worsted cloth is largely made in the loom, but a woollen cloth is really made in the finishing.

Woollen manufacturers largely merchant their own goods, as distinct from the stuff manufacturers, for example, who cater for the wholesale merchant houses. This is perhaps due to the fact that the woollen trade is largely a home trade, the manufacturing of woollen cloths—no doubt owing to its comparative simplicity—being spread over the world. Japan, for instance, already spins, weaves, and finishes woollens, but buys largely worsted tops and yarns.

In Fig. 52 the relationships of the various processes in woollen manufacturing, one to the other, are shown.

CHAPTER XII

THE WORSTED INDUSTRY

THE worsted industry may be said to have risen with the growth and introduction of colonial wools into England. It may be true that its very name carries us back to an industry located in the village of Worsted, in Norfolk, but it is more than probable that did we enquire into this primitive industry we should find that it was principally based upon the production of fabrics which here will be treated under the heading of "Stuffs." For our present purpose, however, it will be convenient to include in this chapter all combed wool yarns and fabrics made entirely of such yarns, along with possibly a few exceptions in the shape of fabrics made of, say, worsted warp and woollen weft. If this is the division adopted, then it is necessary to point out that there are really two distinct branches of the industry—with, of course, many grades in between. Long wools (mostly English) have been combed and made into what are still known to our women-folk as worsted yarns from time immemorial. St. Blaize, a bishop of the fourth century, was the patron saint of the wool-combers, and for how long the industry had been established before his time it is difficult to say. We are fairly safe in assuming that prior to about 1830 worsted or combed yarns were made from long wool of a somewhat coarse and harsh character, and

that the modern "Botany yarn" was unknown. Prior to 1830 fine Continental wools would no doubt be placed on the market as hosiery yarns, but they would be spun on the woollen principle, and were no doubt synonymous with what are to-day termed "merino" yarns. From 1830 onwards the longer colonial merino wools were combed by hand, and about 1840 Lister (Lord Masham) first attempted the combing of short English wools (Southdown), and later of colonial wools, by mechanical means. Prior to this, attempts had been made to comb wool mechanically, but inventors were more concerned with the production of any mechanism which would comb wool, so that we are fairly safe in assuming that the combing attempted was with long wool. Curious to relate, Lister soon abandoned his attempt to comb short wool, becoming more interested in his "nip" comb, which was more suited to the long varieties of wool, leaving the field clear for the Holdens so far as this country was concerned, and Heilmann and the Holdens so far as the Continent was concerned. Thus, from 1850 onwards there has been a steady advance in the capabilities of the machine comb, until to-day the Heilmann and Noble combs will comb wools of, say, 2 inches, which even a few years ago would have been put on one side as being only suitable for clothing purposes. The genesis of the wool comb is illustrated graphically in List I. Every stage therein forms a romance of industry.

It was about the year 1879 that the fine woollen trade was "hit" by the introduction of fine wool "worsteds." Woollen manufacturers, who a few years previously had reckoned their profits in thousands or tens of thousands, either had to change on to the new style of machinery or

had to close down. The fine black cloth—the standard clothing of the middle and upper classes—almost became a thing of the past. Thus it came about that the worsted industry, instead of being almost wholly concerned in the rougher sorts of wools, became more and more concerned in the finer wools, so that to-day it is impossible to say whether the prepared, combed, and drawn long wool yarns or the carded, combed, and drawn short wool yarns form the bulk of the trade. But during the past ten years, again owing to the large supply of a suitable medium wool —neither long nor short—what is known as the cross-bred trade has arisen. Cross-bred wools are usually carded, combed, and drawn, but the yarns produced cannot be compared to Botany yarns for softness and delicacy. To-day, owing to the tendency to produce a big carcass sheep, these wools form the bulk sorts of New Zealand and the coastal districts of Australia and South America, and the yarn and cloth trade in these wools is proportionately large.

The worsted "top and yarn" trade is located in Bradford and district, but some few and not unimportant firms are outside this district. Worsted yarns of the fine, cross-bred and long wool type are woven, dyed, and finished in various parts of the country, each district, as it were, making a speciality of a certain style. Thus Huddersfield leads the world in the finest worsteds for men's wear; Bradford and Halifax are pre-eminent for the cheap production of plain style worsteds for both men's and women's wear; and Scotland now consumes large quantities of cross-bred and Botany yarns, which are made into Scotch tweeds and other fancy worsted styles, mostly for men's wear. The corresponding Continental centres are Elbeuf and Aachen. Of

course, the correspondence is not exact. Thus, while Elberfeld makes linings similar to Bradford, no combing and spinning of moment is to be found there, and so on. Philadelphia and Jamestown are the corresponding United States centres.

The worsted trade, as distinct from the woollen trade, is organized into several distinct divisions. It is true that in certain parts of the country there are firms who buy wool direct, or at the London sales, scour, comb, spin, weave, and finish it. But these firms are the exceptions, the trade as a whole being organized as follows :—

1. **The Wool Buyers.**—This branch of the trade originally bought the wool from up and down the country or in London and resold it to the combers. Of late years, however, there has been a tendency to combine this trade with the combing.

2. **The Combers.**—This branch takes the raw material, scours it, prepares or cards, combs it, and places it on the market in the "top" form.

3. **The Spinners.**—This branch deals with the "tops" as delivered from the combers, converting them by means of drawing and spinning processes into yarns.

4. **The Warpers and Sizers.**—This branch deals with the warping and sizing of the spinning yarns prior to weaving. Thus, warpers and sizers frequently keep standard qualities of their spinners' yarns, and warp, size, and dress on to the manufacturers' loom beam to order.

5. **The Manufacturers.**—This branch weaves into the required fabrics the yarns, etc., supplied by the spinner or the warper and sizer.

6. **The Dyers and Finishers.**—This branch, now largely

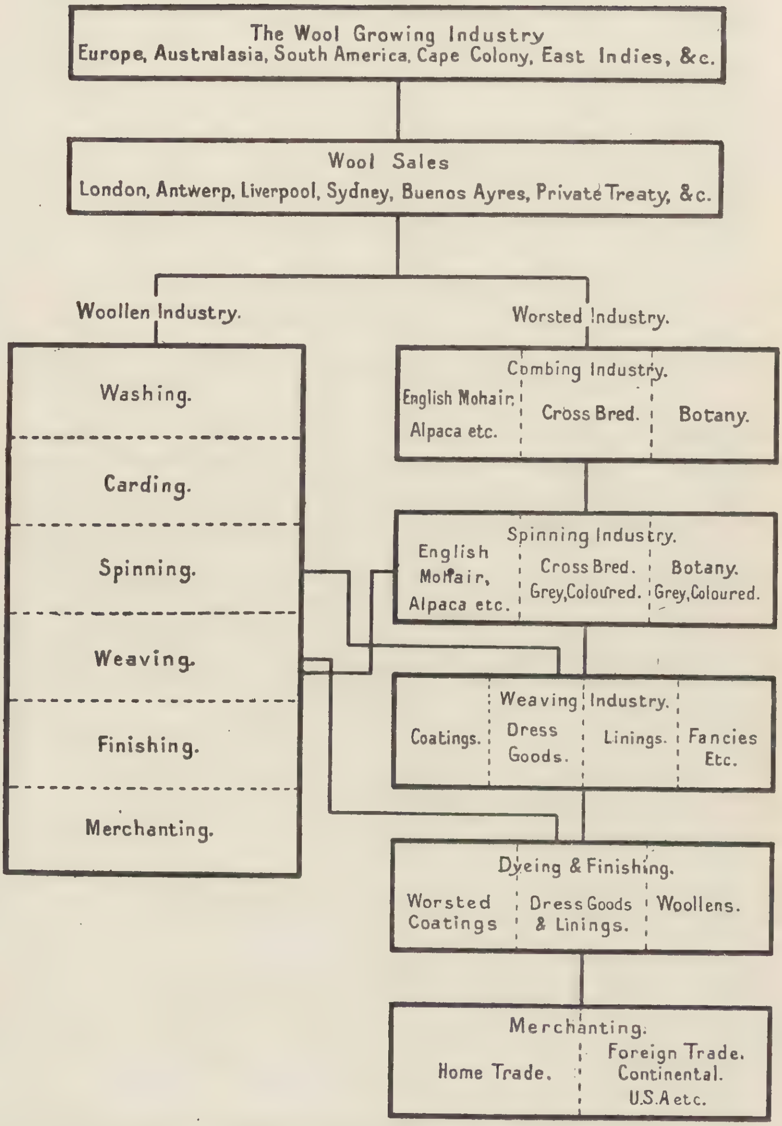


FIG. 53A.—Graphic Illustration of Woollen and Worsted Industries.

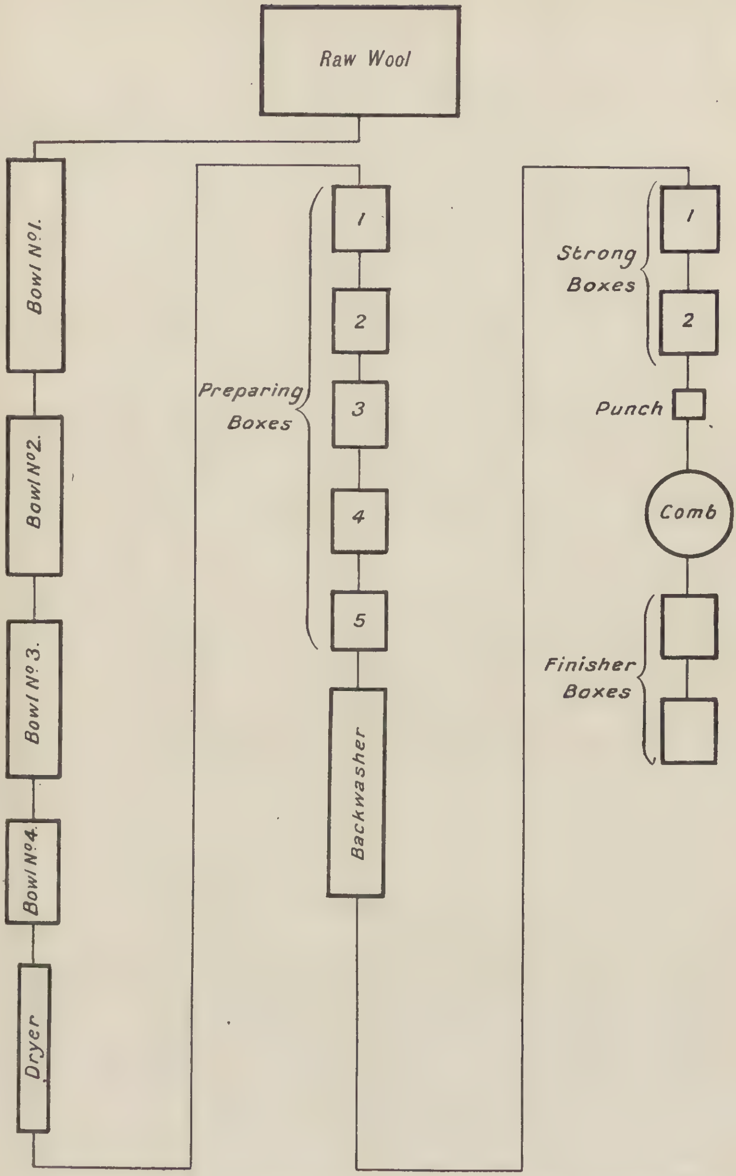


FIG. 53B.—Graphic Illustration of Combing Processes for Long Wool.

organized as a combination under the title of the Bradford Dyers' Association,[1] scours, dyes, and finishes the immense variety of goods forwarded to its various branch works, each of these latter being specialized to deal with particular styles of goods.

7. **The Merchants.**—The large wholesale houses in Bradford at one time almost controlled—and certainly developed—the Bradford trade. To-day there is manifested a tendency for manufacturing concerns to merchant their own goods, but notwithstanding this the merchanting trade of Bradford is in a very healthy condition.

There are several minor branches of the trade in addition to the foregoing main divisions. Thus there are comb-makers, spindle-makers, loom-makers, and the designers and card-cutters.

SETS OF MACHINES FROM WOOL TO THE YARN.

Botany.	*English.*
1 Willow.	1 Willow.
1 Four-bowl Scouring Set.	1 Three or four-bowl Scouring Set.
12 Cards.	1 Dryer.
1 Backwasher.	1 Set of six Preparing-boxes.
12 Sets of two Strong boxes.	6 Nip Combs.
12 Noble Combs.	3 Sets of two finishers.
12 Sets of two finishers.	(Backwashing to be added if required.)
About twelve Sets of Botany drawing would be required to follow this, which partly explains why the Combing and Drawing are organized as separate industries.	About six Sets of English Drawing will be required to follow this.

It is not possible to give details of all the machinery employed in the industry, but the above indicated sets

[1] A few not unimportant dyeing and finishing firms are not in this combine.

of machinery for English cross-bred and Botany yarn production, in conjunction with the information given in previous chapters on preparing, spinning, etc., will enable a comprehensive grasp of the subject to be obtained.

In the worsted and woollen industries the type of work is so miscellaneous that weaving machinery is rarely supplied in sets. In the cotton industry, however, sets are most carefully calculated for specific types of fabrics.

Worsted looms may be run much quicker than woollen looms, an additional speed of at least 20 per cent. often being possible. As a rule, a greater shedding or boxing, or both shedding and boxing, capacity, is required in the worsted loom as compared with the woollen loom, as worsted goods are made in the loom, and not in the finishing, as are woollen goods. Extreme fancy woollens, however, are as difficult and complex in the making as fancy worsteds.

The fabrics produced in the worsted trade may usually be classed under the heading of Botanies, cross-breds, or English. The plainer styles in all qualities are woven in $\frac{2}{\quad 2}$, $\frac{3}{\quad 3}$, $\frac{4}{\quad 4}$ twills and other standard weaves. For women's wear, when fashion is favourable, large numbers of jacquard figured styles are produced, while for men's wear backed and double cloths and very complex schemes of interlacing and colouring are regularly to be met with. Special note should be made of the colouring, as the organization of the Botany coloured yarn trade of Bradford and Huddersfield is unequalled elsewhere in the world, unless it be in the Lyons silk trade.

The finishing of worsted goods has been defined in the

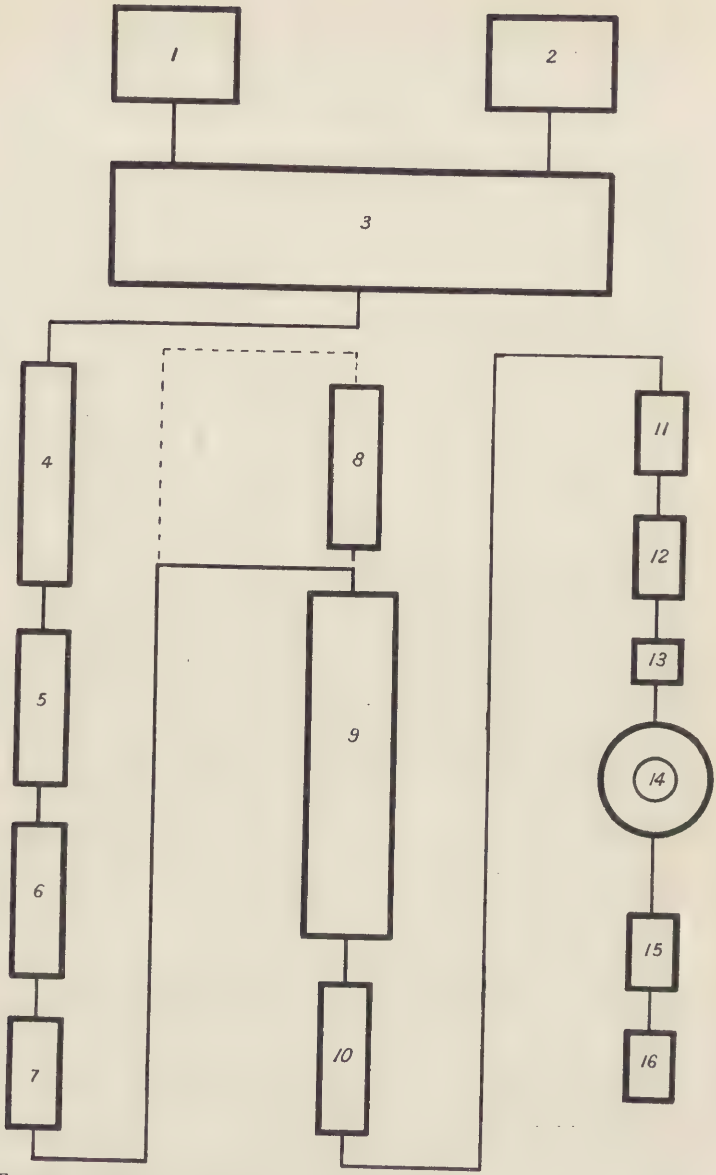


FIG. 53C.—Graphic Illustration of the Combing Processes for Short Wool.—1 and 2, wools to be treated; 3, blend of wools (1) and (2); 4, 5, 6 and 7, washing bowls; 8, dryer (not always used); 9, carder; 10, backwasher; 11 and 12, strong boxes; 13, punch for balling slivers for comb; 14, Noble comb; 15, 1st finisher; 16, 2nd finisher. *Note.*—The balance of machines is not here preserved; thus one set of scouring would keep perhaps twelve combs running (see p. 238).

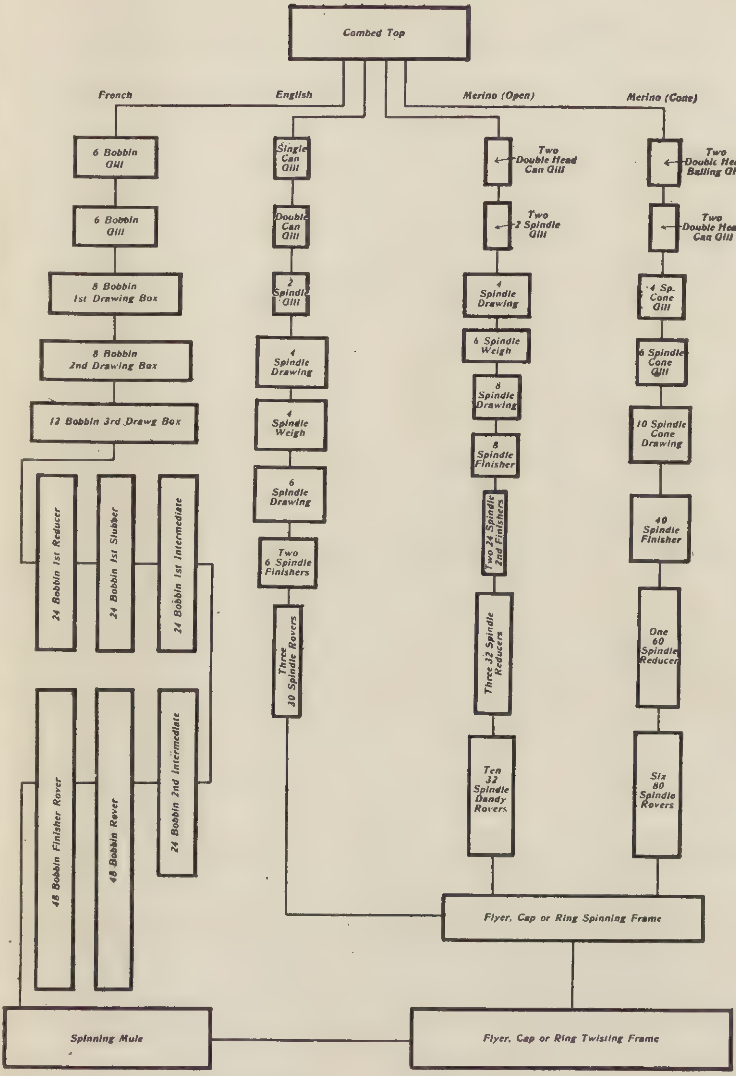


FIG. 53D.—Graphic Illustration of the Drawing and Spinning Processes on the French, English, Merino (Open), and Merino (Cone) Systems.

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chapter on "Finishing." Note should be made, however, of the fact that there are to-day many "worsted finishes." Time was when worsted coatings invariably wore "greasy." Such is not the case to-day—at least, not if the finisher has done his work well. Again, worsteds may be produced soft or crisp at will by maintaining satisfactory conditions. Thus, just as in the case of the woollen cloth, the final product is decided by the primary selection of the raw material, by the way in which that material is prepared and spun, by the way in which the fabric is constructed and woven, and finally by the finishing. It is not one but all these factors which must be considered carefully if characteristic worsted cloths are to be produced.

The merchanting branch of the trade may be conveniently divided into the "home trade" and the "shipping trade." Owing to this division and to the variety of textiles produced, it is questionable whether Bradford should be considered a city of one trade. It is further questionable whether the total trade fluctuation is greater than in a city of recognized diversified trades, such as is Leeds.

The following tables, taken from Mr. F. Hooper's "Statistics of the Worsted and Woollen Trades," convey useful information respecting the "top," yarn, cloth, and dress-stuff trades.

List XI.—Exports of Wool-Waste, Noils, and Tops.

Year.	Total.	
	lbs.	£
1890	21,648,300	1,390,065
1895	31,508,600	1,738,270
1900	37,521,700	2,125,939
1905	58,806,900	3,797,401
1907	57,438,600	4,380,411
1908	55,206,100	3,523,000

List XII.—Exports of Combed or Carded Wool and Tops.

Chief Countries. To	1905. lbs.	1905. £	1906. lbs.	1906. £	1907. lbs.	1907. £
Russia .	1,380,700	100,122	2,400,000	194,834	2,766,600	231,071
Sweden .	4,229,400	301,727	4,650,200	366,161	4,806,200	389,818
Germany	15,189,100	1,033,173	16,605,300	1,265,795	13,808,600	1,090,585
Belgium.	1,668,500	107,976	1,736,600	139,034	2,322,600	179,421
Spain .	1,130,000	93,025	1,347,300	119,161	1,172,600	106,128
Italy . .	5,189,700	353,016	5,620,900	430,787	4,459,000	364,118
Japan .	2,186,000	232,190	2,127,700	257,077	2,253,400	267,511
Total Exports	35,386,300	2,529,395	38,648,600	3,095,664	35,811,300	2,962,893

List XIII.—Woollen and Worsted Yarns.

Year.	Imports. Weight in lbs.	Imports. Value in £	Exports. Weight in lbs.	Exports. Value in £
1860	3,007,711	472,363	27,821,378[1]	3,852,998[1]
1865	4,392,090	998,784	31,671,254	5,429,504
1870	10,294,415	1,635,154	36,605,076	5,182,926
1875	12,428,142	1,472,936	36,523,627	6,065,911
1880	14,947,679	1,842,135	33,464,300	4,222,693
1885	15,888,078	1,995,801	55,684,900	5,580,669
1890	16,379,985	1,935,061	54,042,400	5,260,925
1895	19,597,211	2,042,887	78;813,500	7,258,968
1900	20,525,494	2,163,873	72,568,000	6,123,349
1905	28,274,834	2,697,298	70,707,400	6,173,241
1907	27,075,880	2,684,779	82,702,600	8,569,682
1908	22,495,655	2,302,940	71,303,600	6,616,952

[1] Is for 1862, not 1860.

List XIV.—Manufactures of Wool.

Year.	Imports. Value in £	Exports.[1] Value in £
1860	1,673,197	16,847,956
1865	1,910,758	26,669,636
1870	3,096,257	27,664,051
1875	4,134,213	29,081,836
1880	7,079,848	23,934,541
1885	6,868,837	26,571,537
1890	7,938,918	29,175,989
1895	10,183,586	30,594,568
1900	8,504,782	25,946,037
1905	8,697,121	32,239,922
1907	7,007,775	38,121,270
1908	6,129,099	31,804,445

[1] In this column flocks, shoddy, wools, and waste are included.

List XV.—Imports of Wool Dress-stuffs.

Country.	1905.		1906.		1907.	
	Yards.	£	Yards.	£	Yards.	£
From						
France	77,147,636	5,481,166	76,804,595	5,369,811	60,019,751	4,319,932
Germany . . .	5,572,278	400,186	6,160,626	392,767	5,245,820	430,905
Holland	2,518,659	237,848	2,814,818	267,326	2,970,491	291,861
Belgium	5,026,858	549,482	5,240,970	557,370	6,140,638	608,424
Other Countries .	10,549	553	14,361	1,134	13,835	1,317
	90,275,980	6,669,235	91,035,370	6,588,408	74,390,535	5,652,439
Less Re-exports . .	11,957,942	637,838	10,371,554	570,749	10,216,434	606,143
Net Imports . . .	78,318,038	6,031,397	80,663,816	6,017,659	64,174,101	5,046,296

List XVI.—Imports of Wool Cloths.

Country.	1905.		1906.		1907.	
	Yards.	£	Yards.	£	Yards.	£
From						
Germany . .	1,019,749	155,001	771,668	126,195	520,425	89,236
Holland . .	2,623,690	398,825	2,800,665	386,490	2,290,203	295,860
Belgium . .	362,463	50,564	233,163	35,927	227,138	34,457
France . .	52,143	4,769	37,793	3,156	174,018	20,124
Other Countries	49,103	3,180	46,275	4,245	35,418	3,588
	4,107,148	612,339	3,889,564	556,013	3,247,202	443,265
Less Re-exports	283,434	50,009	329,990	60,486	452,744	71,984
Net Imports .	3,823,714	562,320	3,559,574	495,527	2,794,458	371,281

CHAPTER XIII

THE DRESS GOODS, STUFF, AND LININGS INDUSTRY

It is probable that from the earliest days dress goods and fabrics generally destined for women's wear have been very diversified in material, texture, and design. Tapestries might be more elaborate in design and richer in texture, but certainly not so varied in style. It is probable that for centuries wool textures have occupied a leading position for women's ordinary wear. Coarse woollens of the "winsey" type were no doubt manufactured in bulk for the lower classes; somewhat finer fabrics of the serge type would be the bulk sorts for the better classes along with cashmeres; while the upper classes would more largely patronize silks. Linen was of course largely used as an under-wear, and it is more than probable that, prior to the introduction of the cotton frock, linen fabrics would be used for a similar purpose. Our Eastern trade, dating from the seventeenth century resulted in the introduction of fine cotton goods in the shape of muslins, etc.; but it was quite late in the day before we were able to manufacture these and produce somewhat similar styles in wool under the name of "mousseline-de-laine." It is thus quite easy to understand how the Dress Goods trade of to-day has come to be so comprehensive in its employment of nearly

every textile fibre and every possible combination of the same.

Prior to about 1837 all wool (woollen or worsted), all silk, all linen, and some few wool, silk, and linen combinations, were the standard styles. With the introduction of cotton warps about this time the possibilities of the combination of various materials was more fully realized, resulting in what is known as the "Stuff Trade." Thus cashmere cloths, which, prior to this period, had been made from wool warp and wool weft, were made with cotton warp and wool weft; the Italian cloth, again a cotton warp and wool weft style, was introduced or re-developed; the use of mohair in conjunction with cotton was exploited, resulting in the discovery of a whole range of fabrics variously spoken of as Sicilians, Brilliantines, Orleans, etc.; and a little later Sir Titus Salt placed his far-famed Alpaca styles upon the market. Thirty years later, and the mercerizing of cotton again upset the commercial equilibrium of Bradford. Mercerized goods in a pure form have partially taken the place of the ordinary botany weft Italian, and in their varieties in the shape of lustred (Schreinered) goods and blistered or crepon styles have made a lasting impression upon the fancy dress goods trade.

Largely owing to being first in the field, and to very successful spinning, Bradford has well maintained its lead in such dress goods as involve the employment of English wools, mohair, alpaca, etc., these being termed hard goods as distinct from the soft Botany styles. With these latter styles the French always seem to have been the most successful, simply because of the style of spinning adopted. Bradford early adopted the Danforth spindle or cap frame,

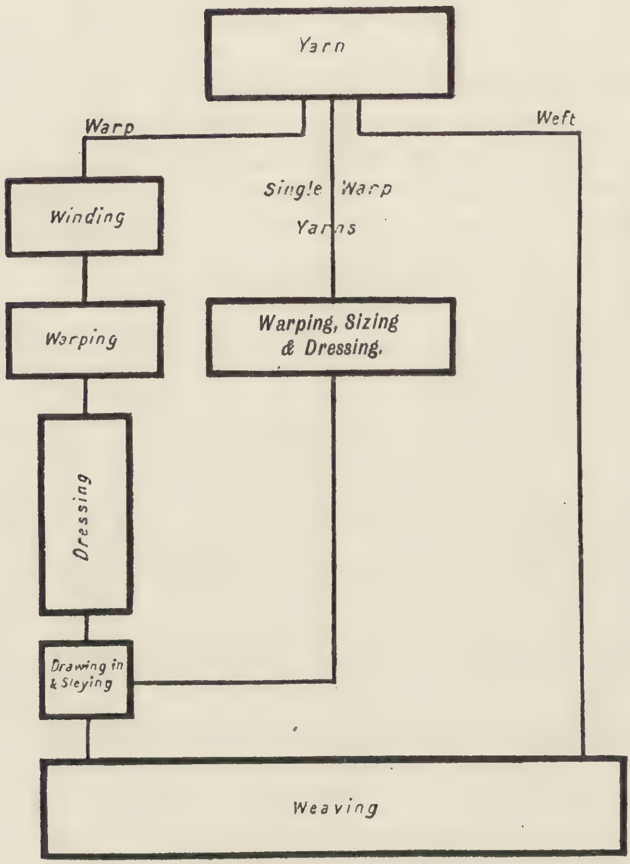


FIG. 53E.—Warping, Sizing, Dressing, etc., Processes.

a spinning machine admirably adapted for the production of sad, solid Botany yarns[1] typically suited to the Italian

[1] Roughness must not be mistaken for fulness. The cap frame can only be considered to spin a "full" yarn in comparison with the flyer frame.

and worsted coating trades. France placed its faith in the mule, and by the time of the Great Exhibition in 1851 had already made a name for soft mule-spun fabrics. From that time to the present, notwithstanding both public and private endeavours, France has well held her own. True it is that when fashion favoured the hard stuffs of Bradford, Roubaix seriously discussed the possibility and advisability of adopting Bradford's method of spinning; but upon the whole they have lost nothing by keeping to the mule. Within the last two years Bradford has again seriously considered the advisability of producing more mule-spun yarns, the Chamber of Commerce taking a strong lead in the deliberations held, and several firms have now successfully overcome the difficulties, both practical and economical, and are placing on the market mule-spun worsted yarns as satisfactory and as cheap as the French yarns. In such goods as Amazons these mule-spun yarns are employed as warp with a woollen yarn as weft. This woollen yarn, of which tons are used in Bradford and Scotland alone, is spun in Belgium and France, no English firm having yet been successful in its economical production. With the success that has attended the attempts to produce mule-spun worsted yarns still markedly in evidence, it will be a strange thing if Bradford does not seriously attempt and succeed in producing this most important woollen yarn.

The Dress Goods, Stuff, and Lining trade is almost wholly located in Bradford and district. In mohairs Bradford still has a practical monopoly, although the piece trade is threatened by the export of "tops" and "yarns" to Continental centres and the United States. In all hard stuffs

Bradford still leads, although both the United States and the Continental centres are gradually becoming proficient in the manipulation of English and cross-bred wools of the long type. Roubaix is the great rival of Bradford, in France, and Gera-Greiz, Tittan, Barmen, Elberfeld, Meerane, and Glauchau in Germany. In the United States the mills are so much engaged in the production of bulk sorts in the local wools that little endeavour has been made to produce Bradford's finest styles, which are thus still imported in fairly large quantities.

The supplies of raw materials are derived as follows:—Oldham and Bolton supply the cotton warps, usually spun from best Egyptian or Sea Island cotton, but sometimes from American; Asia Minor, the Cape, and to a small extent Australia, supply mohair; South America supplies alpaca, vicuna, and llama wool; India supplies cashmere and other wools; England, New Zealand, and South America supply long and cross-bred wool; and Australia, the Cape, and South America supply the fine Botany wools required.[1] Spun silks are now manufactured in Bradford and, close to, at Brighouse, the raw material largely coming from Asia and the latest from the Congo State; while the net silks required are obtained from Macclesfield, the Continent, or China and Japan.

The organization of spinning has been dealt with under the heading of the Worsted Industry. So many and varied are the materials and counts of yarn used by the dress goods manufacturer that it would be an economic impossibility for him to spin the yarns he requires; he must buy on the open market.

[1] Canadian merino wool is just beginning to appear in Bradford.

Cotton warps are delivered in Bradford in the "ball" or "chain" form, and are dressed in the factories on to the loom beam. Mule-spun and delicate wool warps are sized and run directly on to the loom beam by the warpers and sizers, who supply the yarn at a definite price per pound on the loom beam. If it were possible to hank-dye and wind 1-40's cap-spun yarn without undue waste, Bradford would soon develop a coloured dress goods trade. As it is France still retains by far the greater part of this lucrative section of the industry, as Bradford is largely limited to piece-dyeing.

The dress goods manufacturer restricts his energies to the warping and dressing of his yarns and the weaving of the same. His looms may be plain looms, box looms (frequently boxes at one end only), dobby looms or jacquard looms. As the trade is very liable to violent fluctuations from figured styles to plain styles, most fancy manufacturers make arrangements to sling their jacquards up and employ their looms as tappet or dobby looms as occasion demands. The looms used are largely made in the West Riding of Yorkshire. The number of looms in a shed will vary from 50 to 500 or even 1,000 with the accompanying warping, dressing, twisting, weft-room, and grey-room arrangements. The organization is comparatively simple as compared with a combing and spinning mill.

Some so-called manufacturers have no looms at all, getting their goods woven by "commission weavers." These firms are usually very limited in their turnover, although it is but fair to add that there have been some remarkable exceptions.

When figured goods are in fashion the designers and card-cutters form a very important section of the trade.

The larger firms keep their own designing staff and card-cutters, but the smaller firms usually employ one of the independent public designing and card-cutting firms, who supply sketches to select from, point paper designs, and cut cards at a comparatively small price.

The styles of fabrics produced range from plain cloths to elaborate figures. The following particulars respecting (1) a plain lustre fabric; (2) a figured lustre fabric; (3) an all-wool Botany dress serge (cap-spun); (4) an Amazon or soft dress fabric; and (5) a Botany Italian, will give a good idea of the variety of texture to be met with in this trade.

1. *Plain Lustre Fabric:*

Warp.	*Weft.*
All 2/80's Egyptian or Sea Island Black cotton.	All 1/12's Grey Mohair or Lustre English.
40's reed 1's = 40 threads per inch.	46 picks per inch.

Cross-dyed black, lustre finish.

2. *Figured Lustre Fabric: Ground weave plain.*

Warp.	*Weft.*
All 2/100's bleached Egyptian or Sea Island cotton.	All 1/32's White Mohair.
32's reed 2's or 64's reed 1's = 64 threads per inch.	72 to 76 picks per inch.

Finished White.

3. *All-Wool Serge: Weave* 2/2 *Twill.*

Warp.	*Weft.*
All 2/56's Cap-Spun Botany.	All 1/30's Botany.
16's reed 4's = 64 threads per inch.	64 picks per inch.

Dyed any shade required, and given ordinary serge finish.

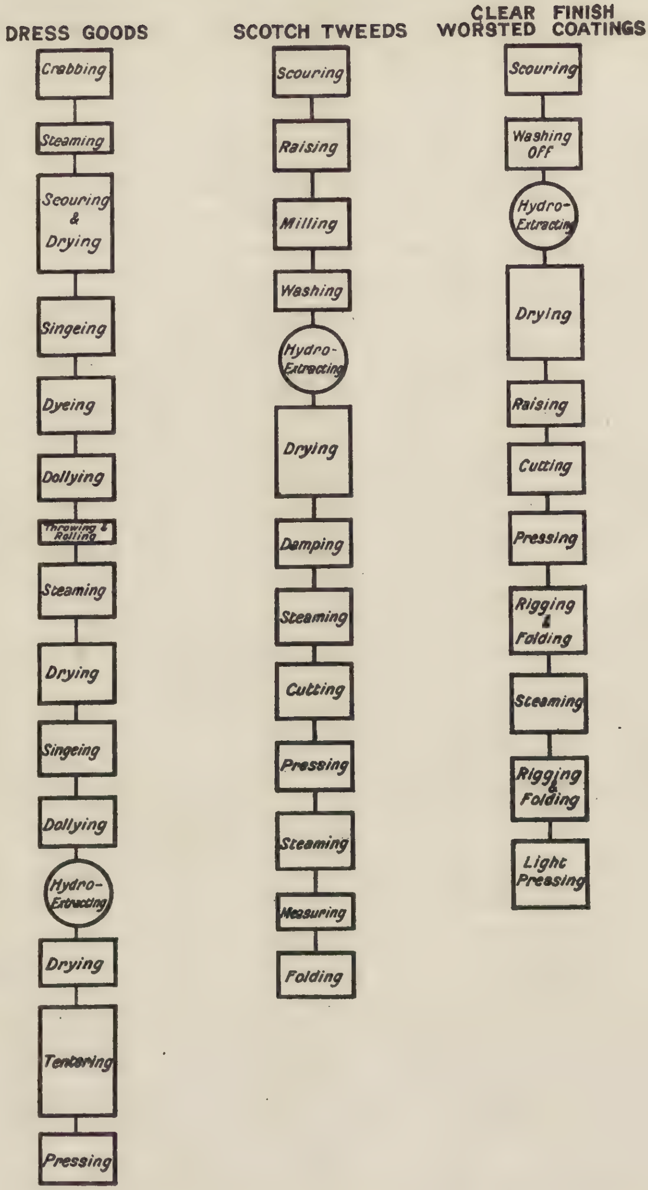


FIG. 53F.—Graphic Illustrations of Dress Goods, Scotch Tweeds, and Worsted Coatings Finishing Processes.

4. *Amazon: Weave: reverse 5* ***Sateen*** *Warp Face.*

Warp.	*Weft.*
All 2/56's Cap-Spun Botany, or 1/30's Mule-Spun Botany. 24's reed 3's = 72 threads per inch.	All 40 Skein Woollen. 36 to 40 picks per inch.

Dyed any shade required, and given a Venetian or Doeskin finish.

5. *Italian: Weave: 5 Sateen Weft Face.*

Warp.	*Weft.*
All 2/50's Black Cotton. 20's reed 4's.	All 1/60's Botany (grey). 120 picks per inch.

Dyed black, and given a solid lustrous Italian finish.

The finishing of dress fabrics, etc., is almost wholly in the hands of the Bradford Dyers' Association, although, as previously remarked, there are a few not altogether unimportant firms outside the combine. If the combine has maintained prices at a high standard, it is but fair to add that they have made most marked advances in the methods of dealing with the large variety of goods continually pouring into their works, and, in addition, have introduced some new finishes of surpassing excellence.

As in the case of the worsted coating industry, there are two marked divisions of the dress goods trade—the home section and the export or shipping section. Again, some firms merchant their own goods, and others work in conjunction with the large merchant houses. Unfortunately, Bradford trade terms are not standardized as are Manchester terms, so that conditions of sale and purchase vary considerably—sometimes for the good of the industry, but, upon the whole, to the detriment of the industry.

The recent development of Bradford's trade in mercerized

goods is worthy of more than passing comment. When, between 1890 and 1900, Bradford first took up this trade it was supposed that it would ultimately drift into Lancashire. Although this has partly occurred, Bradford has considerably more than held its own, and to-day is making large quantities of these goods for both the home market and for export. Of course this trade has cut at the spun silk and in part at the Italian industry, but upon the whole the gain has been much greater than the loss.

CHAPTER XIV

THE TAPESTRY AND CARPET INDUSTRY

The tapestry and carpet industries are frequently but not always allied. It is but natural that we should be able to trace the arts of tapestry and carpet weaving more definitely and perhaps farther back than the art of weaving ordinary fabrics, which, being simpler, did not claim the attention that the production of elaborate tent drapings claimed in the early days of the human race. As already pointed out, it was but natural that elaborate figure weaving should early develop in the family period of the industry, and that elaborate styles of an artistic character, unsurpassed even in these days, were to be met with not only in the eastern but also on the outskirts of the western Roman Empire. The Normans, for example, controlling the labour of England, built cathedrals and churches; in Sicily they not only caused churches to be built, but most elaborate and inspirited tapestries to be woven.

The draw-boy loom was introduced into England from the East during the Middle Ages, and it was no doubt already largely employed on the Continent. This mechanism certainly facilitated the production of large repeating patterns to a very considerable extent. Early in the nineteenth century Jacquard, with some more or less important improvements on the machines of his predecessors

and contemporaries, produced what is known as the Jacquard loom, and about 1830 this machine was successfully combined with the power-loom and made almost as complete a success as the ordinary plain power-loom. So little was the success of the Jacquard power-loom known outside the Bradford district, however, that the writer well remembers in the year 1884 or 1885 a supposed authority in the trade questioning whether it ever could be a success as a power-loom, *i.e.*, twenty or thirty years after it was running by the hundred, or perhaps thousand, in the Bradford district. To-day the tapestry loom is a magnificently harmonised combination of Jacquard, dobby or tappets, box motion, letting-off and taking-up motion, and is employed upon the simplest kinds of tapestries, consisting of little more than reversed warp and weft sateens, up to imitations of the Gobelin tapestries. In Fig. 54 a standard tapestry structure is illustrated.

The carpet trade may be divided into three branches, viz., double-structure or Kidder or Scotch carpets, tufted carpets, and true pile carpets. Double-structure carpets, no doubt, had their origin in stoutly woven fabrics to be employed as floor coverings, probably in the first instance for the ladies' apartments of the old baronial castles in the place of rushes, etc. To make a stouter and better-wearing carpet would naturally lead to the weaving of two cloths together, and from this would come the idea of figuring by an interchange of the two cloths—back to face and face to back—the colourings of back and face fabrics being designed to give the utmost value to this change (see Fig. 55). A special form of the Jacquard loom

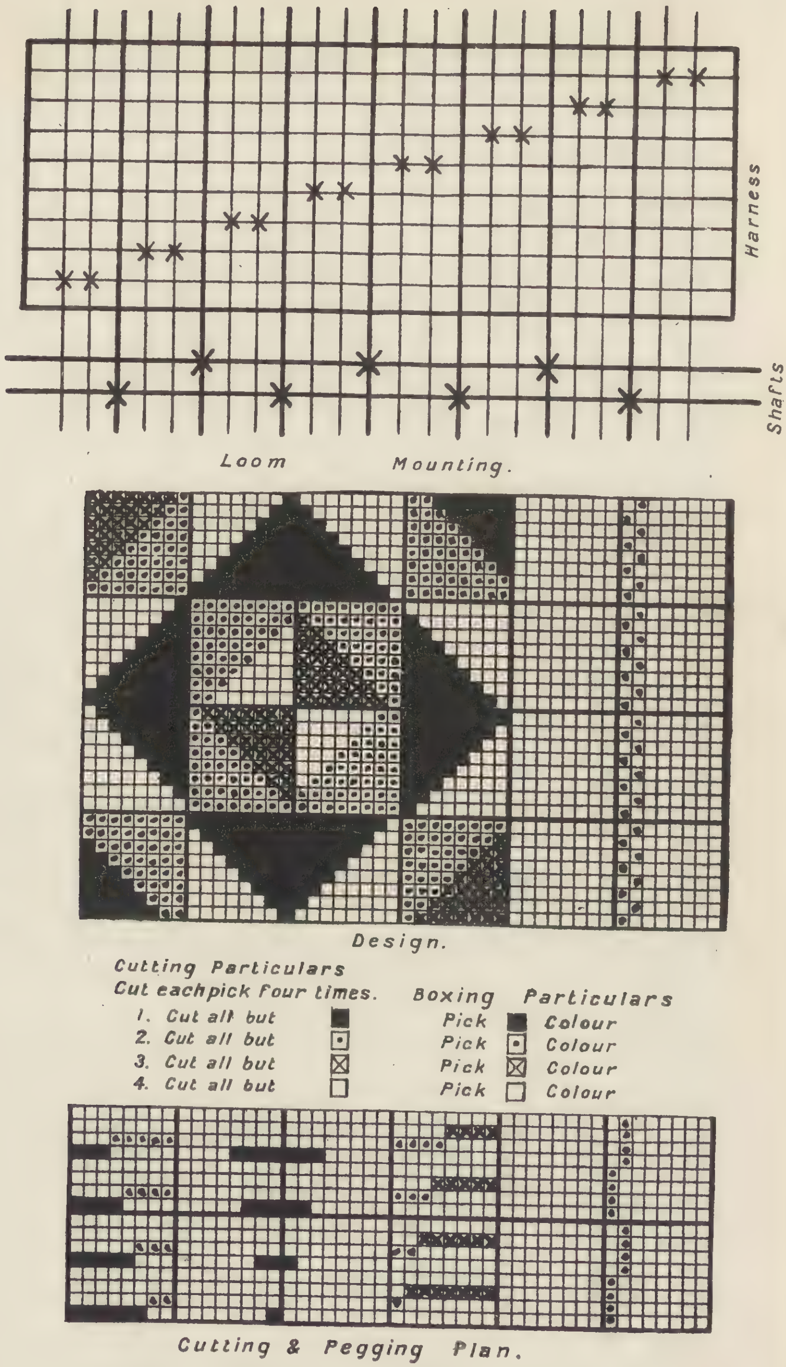


FIG. 54.—Simple Tapestry Structure and Design.

to facilitate the figuring of these goods was also a natural outcome.

Tufted carpets undoubtedly came to us from the East in the first case, Turkey carpets being probably known long before any attempts were made to produce such fabrics in western Europe. Largely owing to the definite endeavours of French statesmen—Colbert, for example—tufted fabrics were made in France during the sixteenth century, and from that date to this the noted Gobelin factory has been turning out most elaborate examples of these fabrics, in many cases reproducing with a most

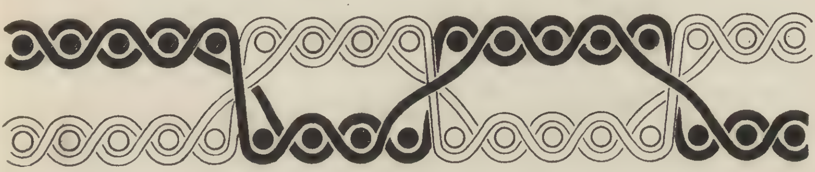


FIG. 55.—Scotch Carpet Structure.

wonderful exactitude the paintings of the most celebrated French artists. A more practical, if somewhat less artistic, hand-loom woven style of tufted carpet was developed during the seventeenth century, and owing to James I., in the seventeenth century, introducing this industry from Flanders into Axminster, in Devonshire, these carpets have become known as Axminster carpets. Briefly, they consist of a firm canvas back or foundation cloth—woven at the same time as the tufts are introduced—into which, row by row, tufts of the colours necessary to produce the pattern are firmly latched in by hand, and cut to the right length. Thus the only limit to this type of design is the

number of tufts which it is possible to insert across and lengthwise of the carpet. As these tufts are now introduced mechanically from bobbins held on bars across the "fell" of the piece, and as the number of bars from a practical point of view must be limited, so is the form design limited in both warp and weft direction (see Fig. 56). There is, however, no colour limitation save such as economy imposes. The Axminster power-loom was invented by Mr. Alexander Smith and Mr. Halcyon Skinner in the United States of America about the year 1856, but it took some twenty years to establish itself in this country. Many modifications of Axminster

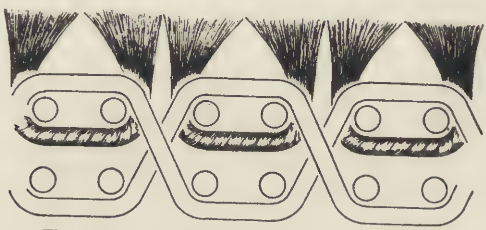


FIG. 56.—Axminster Carpet Structure.

carpets are now placed upon the market. In the most important of these the tufts of colour required in one line across the ultimate carpet are first woven into a gauze thread to form a "chenille" yarn, as many of these variously coloured tufted threads being woven and cut as is necessary to produce the pattern in the carpet, line by line. These are then most exactly woven along with the ground texture of the carpet, the loom throwing in, say, three ground picks, then the coloured chenille pick, and then stopping until the weaver has placed this in "register" to continue exactly the pattern already produced by the previous coloured chenille picks. Then the weaver touches a pedal and the loom

again repeats its four picks and stops. There are many varieties of these carpets, but such is the basis of structure and production of all.

How long wire pile carpets—now called Brussels, Wilton and Tapestry carpets—have been in vogue is difficult to estimate. As the name "Brussels" indicates, the industry originally came to us from Flanders, probably being introduced into Wilton in the year 1770, the development of this industry, as in the case of many other industries, being due in part to the definite interference and endeavours of certain of our sovereigns, and in part to the Continental religious persecutions, which drove skilled fugitives to our shores. Once here, it naturally spread, Glasgow, for example, probably receiving its carpet industry from Bristol by sea, just as Glasgow, in the early part of the nineteenth century, came across the Cashmere shawl from its shipping connection with the East, and evolved it as the "Paisley shawl." Of course, the first pile carpets were hand-woven, but in 1844 to 1850 the United States of America, always on the look-out for labour-saving contrivances, brought out the wire-loom (Bigelow's), in which every motion, from the shedding to the insertion of the wire, was controlled mechanically. Messrs. Crossley, of Halifax, soon took up this mechanism, and upon it built up a colossal concern. They were later followed by others, who applied the mechanism in a variety of ways. The three varieties of this structure are formed as follows:—The true looped Brussels is formed by looping wires and distinct coloured threads (or "frames") for every colour in each row lengthwise of the carpet (see Fig. 57). These coloured threads are lifted over the wires by the Jacquard (*i.e.*, lifted as

required for the insertion of the wires) to form the required pattern. The Wilton carpet is but a cut "Brussels" with certain slight modifications—for example, a slightly modified ground structure and a longer pile. The tapestry carpet is produced from but one pile warp, this warp having the required pattern printed on it in an elongated form, so that when the take-up in weaving is effected the right proportions for the true development of the design will result. As would be expected, the pattern is not so clearly

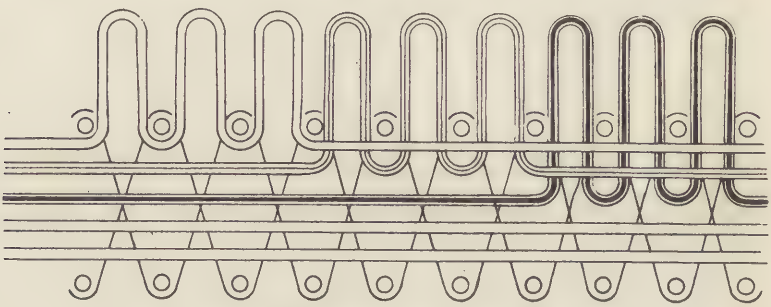


FIG. 57.—Brussels Carpet Structure.

defined as in the Brussels or Wilton carpets, and as it does not contain so much material—having only one pile warp in place of several—it is not so elastic and consequently does not wear so well. The greatest defect of the Brussels or tapestry carpet is the tendency to "sprout," *i.e*, to have long lengths of pile pulled out of them by a nail in a shoe, etc. This, of course, cannot occur with Axminster or Wilton carpets; hence their advantage. Well-woven Brussels carpets, however, should never develop this defect with fair usage. An interesting fact about Brussels, etc., carpets is that if they are not woven in squares they are

usually woven in widths of about twenty-seven inches, *i.e.*, the old Flemish ell and French aune.

The tapestry industry is dispersed over the country, being located principally in Halifax, Glasgow, Bradford, Carlisle, and also being instituted as a "home industry" in Ireland and England on very successful lines. On the Continent the centres are Paris, Roubaix, Berlin, Chemnitz, Crefeld and Vienna. In the United States, New York.

The carpet industry is largely located at Halifax, Glasgow, and Kidderminster in this country.

The materials consumed are silk (both net and spun), wool (chiefly English), mohair, hemp, jute, cotton and China grass.

The mill organization is naturally very elaborate and expensive. Messrs. John Crossley & Sons, of Halifax, for example, have premises extending over many acres and employ 5,000 work-people. They produce Brussels, tapestry and Axminster carpets. The firm of Messrs. James Morton & Co., of Carlisle, is remarkable chiefly because it has organized an elaborate Irish home industry for the production of many articles yet unproducible mechanically.

The methods of production, etc., so closely resemble the methods employed in the dress goods and stuffs industries that little further need be added. The designing room is, of course, pre-eminently important. The art of tapestry carpet designing, for example, is that of using the limitations of structure and colour as bases for design. Again, the mixing, printing, and fastening of the colours upon the threads which are to form the pile in the carpet necessarily claim most marked attention.

Two branches, or rather sections, of the textile industry are not dealt with here, the hosiery industry and the ribbon, braid, and trimming industry. The hosiery industry has now attained to such dimensions and is so intimately associated with the stockinette frame and lace machine that it of necessity claims distinct treatment. The ribbon industry is so intimately connected with the bandolier, lace, and other narrow goods industry that it also is of sufficient importance to be considered as a distinct industry.

CHAPTER XV

SILK THROWING AND SPINNING

SILK manufacture has had the advantage during the last ten or twelve years of competent instruction in the technology of the raw material and its manipulation and weaving, together with its relationships to other textile fibres. The technical colleges of Manchester, Bradford, Leeds, and Macclesfield have made special arrangements and facilities for understanding the whole range of study from the production of the cocoon to the weaving of the fabric.

In the scope of a single chapter it is impossible to attempt any detailed description of the various processes of rearing, reeling, throwing or spinning through which this interesting and beautiful fibre passes before it is fitted for the manufacturer, and we must therefore limit it to general characteristics, and especially as an important article of commerce, to the increase and improvement in character, with the causes which have led up to them.

That there has been an expansion will be seen later on by the figures showing the export from the various silk-producing countries, and the amount consumed by each great centre of manufacture. As far as our own country is concerned there is a general impression that silk weaving has materially decreased, and the closing of throwing

FIG. 58.—Silk Reeling, A.D. 1500.

FIG. 59.—Silk Reeling, 1900.
By permission of Messrs. Giov. Battaglio, Luino, Italy.

mills and silk factories in Derby, Nottingham, Coventry, Macclesfield, and other towns gives colour to this conclusion. But it must be remembered that great economic changes have taken place during the last thirty to forty years. London is no longer the port of debarcation for the Eastern silks of China and Japan, and consequently the centre of distribution. The East India Company has ceased to hold responsibility for the importation and sale of our East Indian colony. The shipping companies now disembark their silk freights at Genoa and Marseilles as well as London, and the Japanese send a large contingent of their production across the Pacific to the American continent. Then, again, the evolution of the power-loom and its adaptation for silk weaving has practically displaced the occupation of the old hand-loom weaver, and by its introduction a single operative will be producing four times the amount as in the former days by the older methods. A general desire for cheap fabrics within the purchasing power of the million has greatly stimulated the mixed goods trade, and the looms of Scotland, of Yorkshire, of Lancashire and other districts are now engaged in weaving this textile in combination with others, especially with mercerized cotton and wool. In spinning and throwing, by the introduction of better reeled silks, and the adoption of the faster running gravity spindle, the production has been nearly doubled, and consequently an equal weight is turned out with one half of the labour formerly employed. It is, of course, natural that those countries where the raw material is indigenous will endeavour to take a first place, or where, as in the case of America (a self-contained continent), a desire is manifest to retain the supply of its people in every

The World's Silk Supply.

Raw Silk Production and Exportation.	Average for Five Years.			1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.
	1876-1880.	1881-1885.	1886-1890.								
France	11,220	13,882	15,224	12,452	14,080	18,744	19,712	17,160	17,248	13,640	12,100
Italy	41,800	60,720	72,842	70,620	65,230	87,648	75,878	68,904	67,826	64,152	65,824
Spain	1,430	1,892	1,584	1,980	1,584	1,694	1,980	2,200	2,244	1,606	1,760
[1] Austria-Hungary	—	3,366	5,830	6,182	4,840	5,346	5,852	6,050	6,468	5,082	5,368
Brutia	1,870	3,080	4,092	2,970	4,532	7,216	7,810	6,600	9,130	6,952	9,064
Syria and Cyprus	3,456	5,170	6,688	6,380	7,700	11,440	10,252	8,250	9,240	10,780	10,230
Salonica and Adrianople	1,782	2,222	2,948	4,180	4,840	5,500	4,070	3,410	3,740	2,530	3,630
[2] Bulgaria, Servia, Roumania	—	—	—	—	—	—	550	792	990	814	748
Greece and Crete	572	418	462	660	770	990	836	924	880	946	880
Caucasus / Exportations: [3] Persia and Turkey	6,380	4,510	2,046	4,180	3,960	4,400	3,850	4,070	5,500	5,280	5,060
Exportations: [3] Persia and Turkey				—	—	—	—	660	1,056	2,310	2,926
Exportations: [4] Shanghai	72,336	53,856	60,676	84,348	89,452	92,730	83,314	93,412	85,470	86,350	102,300
Exportations: Canton	19,514	19,668	28,094	26,422	32,472	28,292	29,788	34,100	37,202	40,920	50,490
Exportations: Japan	22,726	29,920	45,232	65,868	62,876	59,070	67,848	75,020	65,978	77,154	68,684
Exportations: [5] Calcutta and Bombay	11,704	8,932	9,482	5,038	5,500	6,314	4,378	7,480	5,940	6,402	6,050
Total in Bales of 100 lbs.	194,790	207,636	255,200	291,280	297,836	329,384	316,118	329,032	318,912	324,918	345,114

[1] Austria-Hungary before 1881 was included with Italy.
[2] Bulgaria only commenced silk reeling in 1900.
[3] Persia. There were no exportations previous to 1897.
[4] China. Before the year 1890 Tussah Silks were not included in the returns.
[5] Kashmir. From 1905 the production of this province is included with exports from India (shipped from Bombay).

The World's Silk Supply—*contd.*

Raw Silk. Production and Exportation.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
France	12,320	16,192	14,388	12,540	10,428	13,750	13,904	13,310	14,564	14.430	14.830
Italy	73,986	99,792	94,380	98,494	77.572	107.800	97,680	104,390	106,040	98,690	93.520
Spain	1,716	1,848	1,760	1,716	1.892	1,694	1,716	1,232	1,650	1.650	1.760
[1] Austria-Hungary	6,072	6,886	7,150	6,864	6,050	6,930	7,590	7.524	7,920	7.350	8.360
Brutia	10,692	8.360	9,196	11,066	11,572	10,934	14,212	12,188	14,630	13.530	14.960
Syria and Cyprus	10,032	9,900	9,350	11,880	11,220	10.340	10,780	10,340	11,770	10.780	12.650
Salonica and Adrianople	4,620	3,300	4,400	4,180	5,456	5,632	6.160	5,654	7.480	6.270	6.930
[2] Bulgaria, Servia, Roumania	924	1,672	2,112	2,860	2,992	3,366	4,180	4,070	4,730	7.750	6.930
Greece and Crete	748	1,100	1,320	1,430	1,320	1,430	1,540	1,650	1,672	1.430	1.540
Caucasus	6,820	7,700	9,680	10,230	8,800	7.920	6,380	10,010	10,780	7.920	11.880
Exportations. [3] Persia and Turkey	5,412	6,820	5,610	12,100	14,300	9.372	10,120	13,816	13,420	11.570	13.200
Exportations. [4] Shanghai	120,010	101,772	111,408	79,200	93,368	92.730	88,220	93,764	96,360	124.040	112.200
Exportations. Canton	49,500	44.132	47,124	48,818	47,234	46.948	44,000	43,164	49,500	52.320	48.070
Exportations. Japan	77,924	90,750	99,000	104,940	101,376	128,194	101,618	131,824	139,700	166.540	180.400
Exportations. [5] Calcutta and Bombay	7,700	6,160	6,160	6,490	5,390	3,960	6,160	7,150	7,480	5,500	5.170
Total in Bales of 100 lbs.	388,476	406,384	423,038	412,808	398,970	451,000	414,260	460,086	487,696	529.770	532.400

1 Austria-Hungary before 1881 was included with Italy.
2 Bulgaria only commenced silk reeling in 1900.
3 Persia. There were no exportations previous to 1897.
4 China. Before the year 1890 Tussah Silks were not included in the returns.
5 Kashmir. From 1905 the production of this province is included with exports from India (shipped from Bombay).

department of industry in its own hands, which they now do by a heavy protective tariff. The following table of silk production and export of the various countries where sericulture is carried on shows clearly that the weight has been more than doubled during the last thirty years. These figures do not include the silk used by the natives of China, Japan or India, and we know that they retain a very large contingent of their reelings for native manufacture both for home consumption and export of fabrics.

Table showing Silk Production and Export of the various Countries (in Bales of 100lbs. each).

<table>
<tr><th>During Years. Average per annum.</th><th>From Europe.</th><th>Levant.</th><th>India.</th><th>China.</th><th>Canton.</th><th>Japan.</th><th>Totals. Average per annum.</th></tr>
<tr><td>1870 to 1874</td><td colspan="3">105,250</td><td>56,915</td><td>19,110</td><td>14,400</td><td>195,675</td></tr>
<tr><td>1875 to 1879</td><td colspan="3">78,320</td><td>67,520</td><td>17,666</td><td>17,560</td><td>181,066</td></tr>
<tr><td>1880 to 1884</td><td colspan="3">109,400</td><td>63,050</td><td>18,090</td><td>24,970</td><td>215,510</td></tr>
<tr><td>1885 to 1889</td><td>90,700</td><td>14,670</td><td>17,330</td><td>56,715</td><td>23,200</td><td>41,860</td><td>244,475</td></tr>
<tr><td>1890 to 1894</td><td>93,580</td><td>17,760</td><td>5,775</td><td>68,585</td><td>28,510</td><td>58,505</td><td>272,715</td></tr>
<tr><td>1895 to 1899</td><td>93,820</td><td>29,700</td><td>7,100</td><td>77,900</td><td>43,300</td><td>72,375</td><td>324,195</td></tr>
<tr><td>1900 to 1904</td><td>93,525</td><td>46,635</td><td>6,050</td><td>96,435</td><td>46,280</td><td>98,630</td><td>387,555</td></tr>
<tr><td>1905 to 1907</td><td>124,905</td><td>53,080</td><td>5,755</td><td>90,250</td><td>45,070</td><td>120,440</td><td>439,500</td></tr>
</table>

The above table requires some explanation. Up to the year 1884 statistics of the countries of Europe were grouped with those of the Levant and India, and it is therefore difficult to ascertain which country was best developing its resources. From that period up to the present time the yield in Italy, Austria, and Hungary grouped together has increased 50 per cent. The Levant and Central Asia has trebled its production. India appears

to show a decline, owing partly to the withdrawal of the fostering care of the East India Company. From another table, which we append, it will be seen that India manufactures more silk than it exports, so that it is difficult to ascertain its full complement of production. The Chinese, doubtless, retain fully one-half of their out-turn for home consumption, and Japan probably one-third. This last-named together with the Cantonese, owing to their extended cultivation of the mulberry and their improved methods of reeling, account for the largest increase. It is well known that their manufacturing requirements have increased in like proportion. The following table (p. 272), shows the production and consumption of each country at the present period.

The cause of this increased output is not attributable to a single department of its cultivation and manipulation. All along the line Western science has been brought to bear, resulting in improved methods of rearing, reeling, and spinning. In France alone the production, which in the year 1820 reached 1,000,000 lbs., trebled itself during the following decade, and between the years 1840 and 1855 the estimated production was 4,500,000 lbs.; but this excessive development brought in its train serious consequences. The large breeders brought millions of worms together in one room, an overcrowding which induced a serious disease, and nearly threatened the extinction of the species throughout the whole of Southern Europe, and more or less in China and Japan, but without such serious results in these last-named countries.

This catastrophe, however, laid the foundation for greater care in the breeding, and consequently for the better results

PRODUCTION AND CONSUMPTION OF RAW SILK.

		Production Average of Seasons 1903/04, 1904/05, 1905/06	Consumption of same. Average of years 1902, 1903, 1904.
EUROPE:	France	12,760	95,194
	Italy	92,334	21,252
	Switzerland	990	35,090
	Spain	1,760	4,026
	Austria	3,608	17,072
	Hungary	3,234	
	Russia and Caucasus	8,932	27,962
	Bulgaria, Servia, Roumania	3,432	374
	Greece and Crete	1,386	440
	Salonica, Adrianople	5,742	660
	Germany		62,612
	England		15,598
AMERICA:	United States		134,816
ASIA:	Brusa	12,078	660
	Syria	11,000	2,420
	Persia (exportation)	5,566	No Estimate.
	Turkestan ,,	6,006	
	China ,,	89,606	
	,, Canton ,,	46,618	
	Japan ,,	111,364	
	India ,,	5,632	7,700
	Tonquin and Annam (exportation)	220	
AFRICA:	Egypt		4,400
	Morocco		1,540
	Algeria and Tunis		1,430
	Other Countries		1,210
	Bales of 100 lbs.	422,268	434,456

N.B.—Two reasons account for the seeming excess of consumption over production: 1. The figures of production being based upon seasons, and that of consumption upon calendar years, both columns do not refer to exactly the same period. 2. For several years the Italian crop has been officially underestimated.

of which we now reap the benefit. The whole world of sericulture will ever be indebted to M. Pasteur, who in the year 1865 was called to the rescue from what in France was looked upon as a national calamity. After two years of close study and experiment he succeeded in discovering and pointing out the cause of the malady and the means of preventing it. In the first place, healthy seed was imported from Japan, the country which had least suffered, and so the practice of cross-breeding became universal, and amongst the best "graineurs" to-day great care is exercised in the selection of the finest cocoons from the various districts in order to establish new and healthy breeds of silkworms. The main remedy was effected by the practice of "cellular incubation," viz., the examination of the eggs under the microscope, in order to ascertain if the production of each moth had within it the source of infection for a future race. During the next ten years this method of inspection was adopted by every well-ordered establishment, in every country, with the exception of the Chinese, who still suffer from year to year by their antiquated methods both in quality and quantity of the seasons' yield.

A book recently published by M'Laurent de L'Arbousset, of Alais, France, and translated from the French by Elizabeth Wardle, the talented daughter of the late Sir Thomas Wardle (President of the Silk Association of Great Britain and Ireland), reveals to us other causes of improvement than those of interbreeding and microscopical inspection, important as they are. The mulberry, the staple food of the *Bombyx mori*, is now cultivated under the most methodical and improved conditions, and calculated to afford the highest degree of nutrition. By careful selection

of healthy stock plants, grafting, pruning, and judicious gathering of the leaves, especially during the earlier growth, a more succulent and nourishing food is obtained and the trees are better able to resist the fungoid diseases to which they are liable. Magnaneries (rearing sheds) are more carefully warmed and ventilated, the silkworms are better spaced, and by cleanliness and mild fumigations of sulphurous acid or formalin the silkworms are kept freer from the diseases to which they are liable, and consequently spin a more robust cocoon, better in quality and the thread of greater length. In marketing the cocoons they are classified as to quality, and in stoving (with the object of killing the chrysalide) new and improved apparatus has been introduced. The peasants in country districts adopt very primitive means of effecting this. One method described by this writer is that of subjecting them to the baking process. After the bread has been withdrawn from the baker's oven, the bare arm is thrust into it, and, if the heat can be borne without scorching, the cocoons, placed in baskets, are then inserted and retained until the operator is satisfied that life no longer remains. Steaming, however, gives a much better quality of fibre, and in the absence of specially-constructed apparatus they are placed in baskets over a copper of boiling water, and after a complete desiccation spread out in the sun to dry thoroughly.

By the adoption of the foregoing methods the net yield from one ounce of graine, or eggs, has during the last twenty-five or thirty years been trebled, and in many instances quadrupled. It is now calculated that from this incubation of healthy and carefully-selected seed seventy

kilos of cocoons may be produced, 90 per cent. of which are of the first quality. But we pass on to note the stages by which the reeling has been brought up to its present standard of efficiency in the improvement of the reeled silk and the lowered cost of production. In the year 1820 a

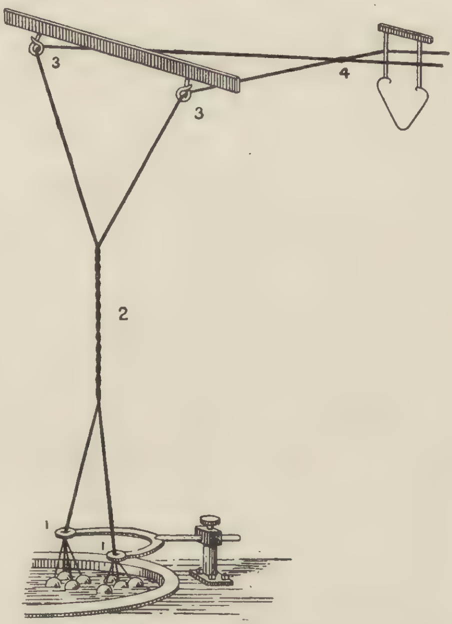


FIG. 60.—Croissure by the System Chambon.

French inventor, Gensoul, of Bagnols-sur-Lèze, introduced the process of heating the reeling basins by steam, which, by removing a separate oven for each basin and the driving of each reel separately by hand, enabled the workers to be placed nearer together on one table, and by one driving-wheel the whole line of reels are worked by the same motive power.

In 1828 a further improvement was introduced by Chambon, of Alais, which established the universal use of the Croissure which improved the reeled threads by making them rounder and more compact and homogeneous. Unfortunately this apparatus gave rise to what is known in the

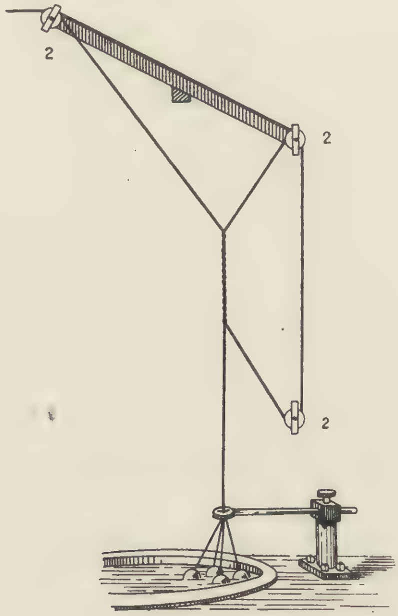


Fig. 61.—Croissure by Tavalette.

trade as "mariages," or double threads running parallel together on the reel and needing separation in the winding and throwing of the silk for manufacture. This has been obviated by the use of the Tavalette croissure, each separate thread being crossed upon itself (with thirty to forty turns), and is carried singly by means of small pulleys on to the reel. The waste material on the outside of the cocoon,

which had to be removed by the whisking of a brush in a separate basin, and by hand, is now effected by automatic machinery. The work of one reeler was under the older system confined to two sets of cocoons. (From four to six threads or cocoons are combined to make one thread of

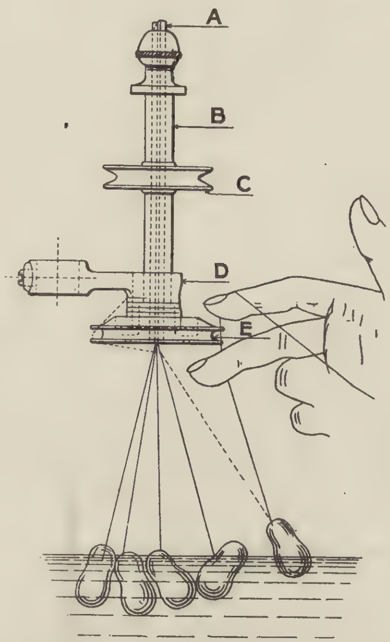


FIG. 62.—The Jette-bout, combining Five Cocoons in One Thread.

raw silk.) Now, under the new conditions, the reeler can easily superintend in one enlarged basin from four to six sets of cocoons, in addition to which the reels can be driven faster. In spite of the mechanical improvements in the apparatus used, it is necessary that great care should be exercised in order to avoid those defects which would impair

FIG. 63.—Duvet.

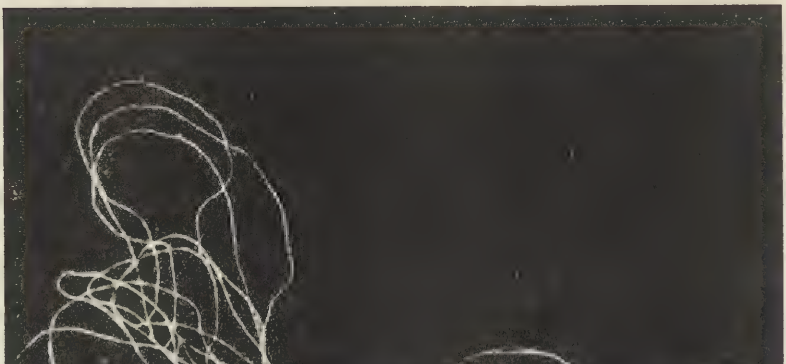


FIG. 64.—Bouchons or Slubs.

the quality or cause trouble in the weaving. A few of the imperfections to which bad reeling gives rise may be indicated. First, *Duvet* gives the appearance of short fibres thrown off from the main continuous thread. This was attributed formerly to the silkworm spinning an imperfect bave on the cocoon; but while there may be variation in thickness between the first and last end of the spun thread, there is no mechanical imperfection caused naturally. The microscope reveals to us the real cause, either frequent and

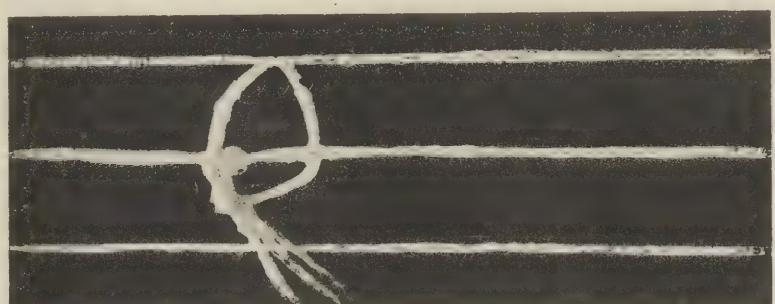


FIG. 65.—Knots.

imperfect joinings as the cocoons become attached to the main thread, or still more by an uneven temperature in the reeling basin (which should be kept at 140° to 160° Fahr.), thus causing the silk to unwind itself unevenly and cause small loops. Secondly, *Foul* or *Slubs* (bouchons) present a more aggravated form of the above-named defect, the layers of the thread on the cocoon coming off *en masse.* There are few productions actually free from this fault, and the native reelers of China silks are so careless that it is only by passing the thread through cleaners (steel blades

closed so as to stop the bouchons) that their productions can be utilized. Thirdly, *Knots* are unavoidable, but by careful oversight they may be minimized, and under any circumstances be neatly made. Fourthly, *Baves* imperfectly joined together give the thread an open and soft appear-

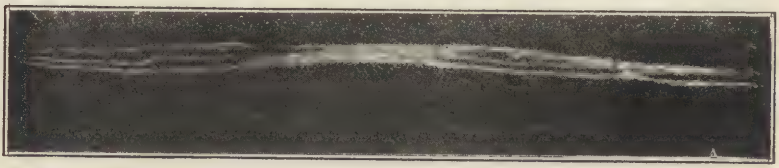


FIG. 66.—Baves imperfectly Joined.

ance. They are mainly caused during a temporary stoppage of the reeling, some of the threads from the cocoon drying more quickly than others. Fifthly, *Vrilles* give the thread a crêped appearance, and are produced by the breakage of one of the baves when it is necessary to reduce the number of the cocoons.

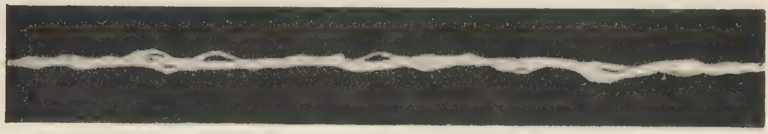


FIG. 67.—Vrilles.

Most of these faults may be discerned while the silk is in the raw or gum state. During the last decade a much graver imperfection (but not new by any means) has formed the subject of controversy amongst experts. It is known as *silk louse*, causing an appearance when discharged or dyed and wound on the bobbin of specks of dust. When

placed under a high power of the microscope these minute specks present the appearance of numberless fibrils indicating a rupture and division of the original bave and brin of the silk. It has been variously attributed to (*a*) the use of disinfectants in the rearing sheds chemically disin-

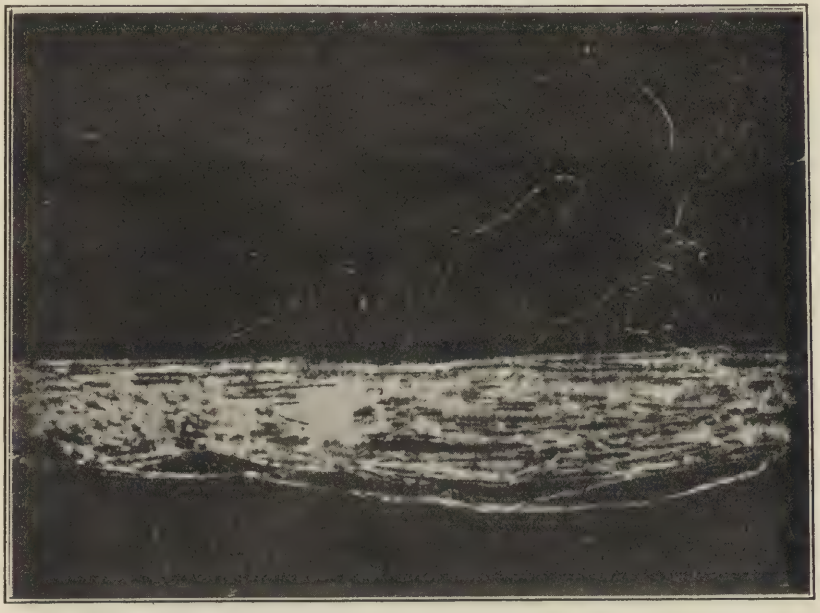


FIG. 68.—Silk-louse.

tegrating the fibre; (*b*) an imperfect croissure, the reeler failing to give the necessary number of turns of the thread upon itself; (*c*) undue punishment in the process of boiling, dyeing, or lustreing, specially the latter. So far no satisfactory solution has been arrived at, and it is most probable that it may arise from a combination of causes.

Certain it is that some classes of silk are more liable to it than others, and as the appearance is only spasmodic there may be certain seasons and countries where the conditions of rearing and reeling are unfavourable.

In the production of a good weaving thread it is equally necessary that the throwster should take every precaution either to minimize by cleaning the reeling defects of the raw silk, or, by good machinery and careful oversight in his own processes, avoid the production of faults incidental to this particular process of manipulation. A brief *résumé* of the work of the throwster may not be out of place. In dealing with the raw silk for throwing, the treatment should be varied according to quality. The filature silks of Italy, China, and Japan are fairly even in size, and the skeins are reeled in hanks suited for winding without separation, whereas those of China reeled by the natives come to us in mosses or hanks weighing nearly 1 lb., and require very carefully splitting into smaller hanks. They are usually so uneven in the thickness of the thread that it is necessary to classify them, otherwise the union of a thick and thin thread produces in the two-folded tram or organzine a loopy or crinkled appearance, which is a serious fault and drawback to the after-processes in the manufacture. Where the silk in reeling has touched the arms of the reel a hard gum is formed, and requires carefully softening either by the immersion of that portion of the skein in a softening emulsion or by a complete washing of the bulk in a soap bath. The cost of winding varies according to the method of reeling. Those silks produced in well-equipped filatures or factories are as nearly perfect as possible, and one worker can superintend 80 to 100 spindles, the bobbin taking up

50 metres per minute, as against inferior native silks 20 to 25 spindles, and the waste caused by these latter is much heavier. In the next process of cleaning equal care is required, so that all the bouchons or foul may be eliminated,

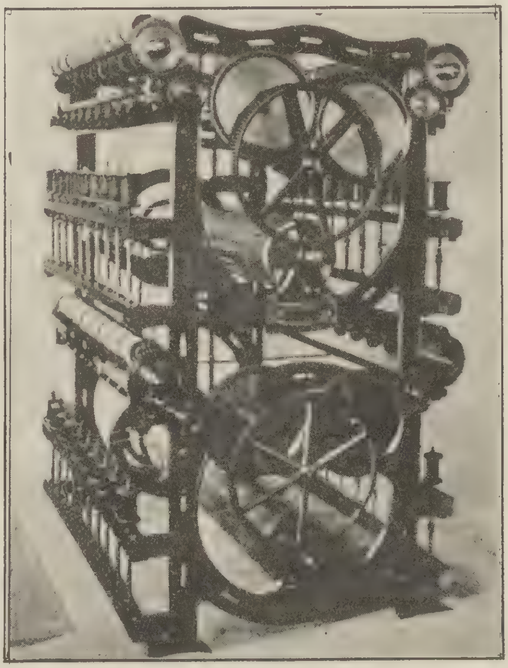


FIG. 69.—The Ritson Spinning Mill.

and where tied out a neat knot should be made and the ends cut off shortly. The process of doubling two or more threads together requires equal vigilance. Two ends of equal size should be run together, the tensions on each carefully adjusted, and each thread passed through an automatic faller or eye, so that one thread cannot pass on to the

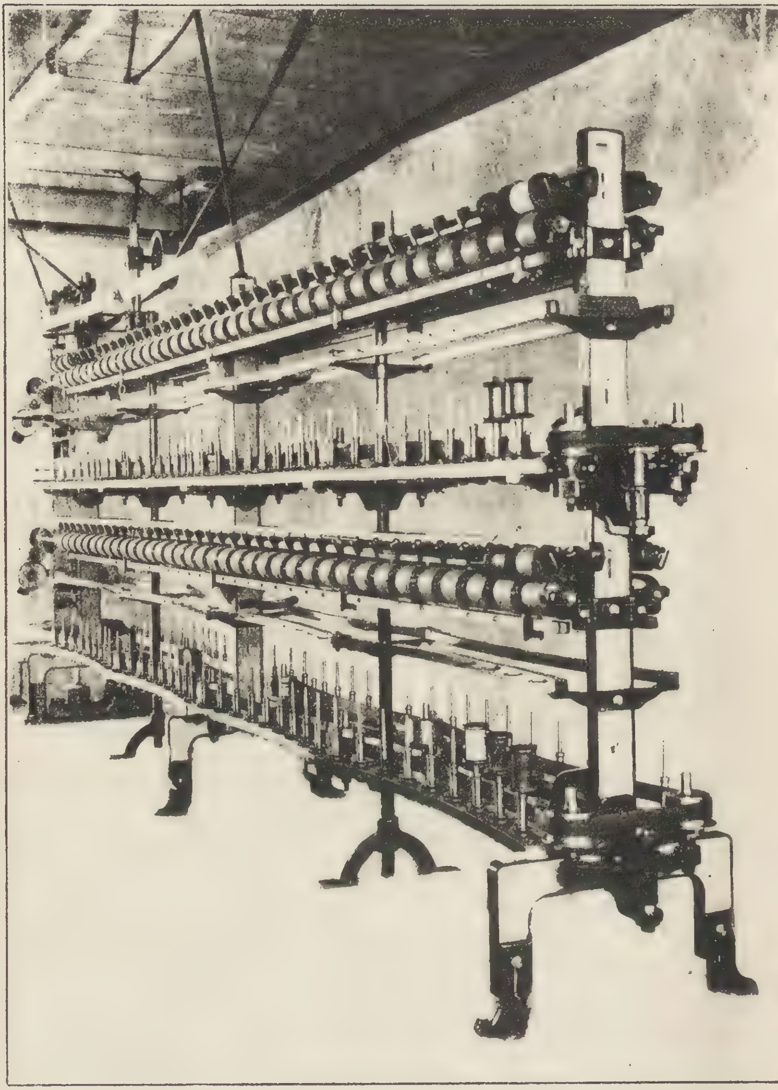


FIG. 70.—Spinner (new type).

bobbin singly. In spinning, doubling, and twisting marked improvements have been effected in late years by better and faster-running machinery. The Ritson spinning mill, introduced in 1830, with a separate cotton band for each spindle driven by a cylinder, was only capable of doing

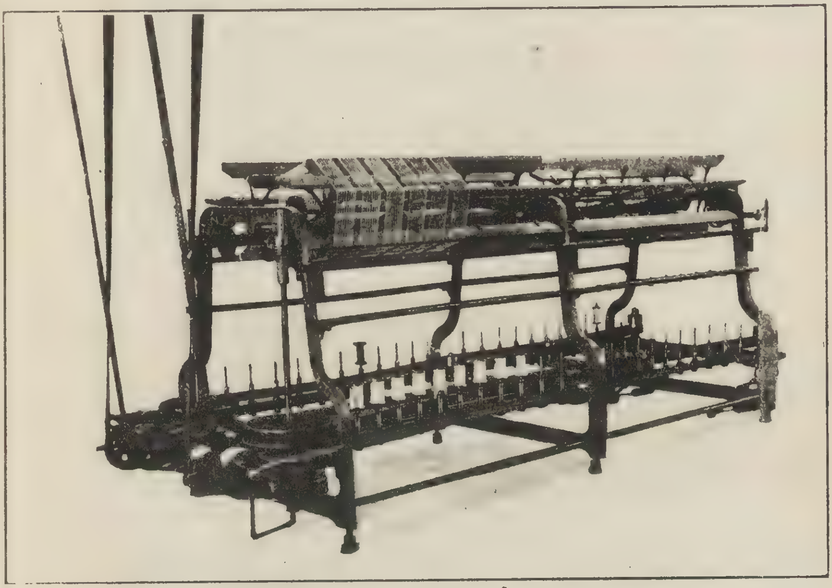


FIG. 71.—Throwing Mill, Twisting and Reeling Combined.

effective work at 3,000 to 4,000 revolutions of the spindle per minute.

This has been superseded by machinery furnished with gravity spindles, which are successfully run at the rate of 8,000 to 10,000 revolutions per minute. In addition to this advantage the machine only takes up two-thirds of the room of the older type. In some cases the final twist is given

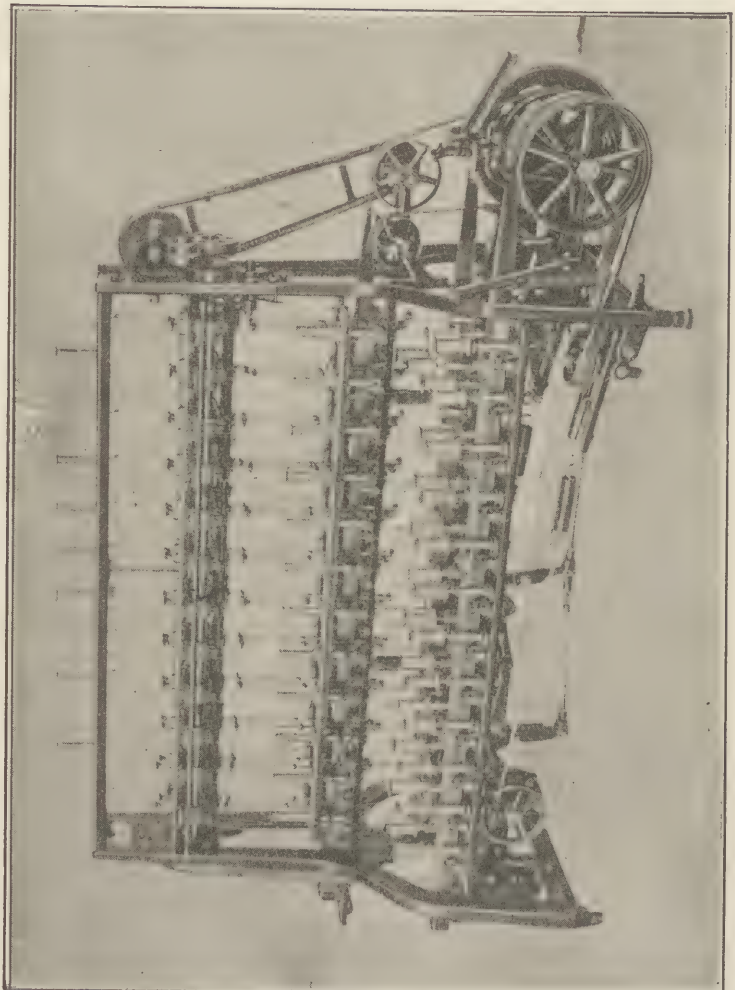


FIG. 72.—The Bradley Spinner Compound Processes.

on the same type of machine and the doubled thread reeled on a separate reeling machine with automatic stop motion, so that each skein is of an equal length. The more modern and equally effective method is to twist and reel at the same time. A twisting frame built on similar lines to that of the spinning mill, but with reels instead of take-up bobbins can be driven at the rate of 6,500 revolutions per minute. The latest American machine provides for spinning, doubling, and twisting in one process, but so far it can only be adapted for the most perfectly reeled silks of Italy and Japan of 14 to 16 deniers in the thread. Finer reeled silks and those of a commoner description would suffer in quality, and little if any advantage in cost would be gained by the adoption of so compounding the processes. One of the greatest advantages of late years has been gained by the process of cross-reeling known as the Grant system, by which a length of 5,000 to 10,000 yards can be reeled in one skein. The silk is kept straighter in the dyeing process, and the winding is facilitated, and at one-half of the original cost as against the smaller hanks.

As compared with other textiles made from short fibres, net silk has distinctive qualities which give to it a precedence over them. For instance, its natural brilliancy, transparency, and absorbent character enables the dyer to incorporate with it tannic acids or metallic salts, in some cases up to double its original weight, and increasing bulk up to 50 to 100 per cent., without in any way impairing its natural lustre, and at the same time so incorporating itself as part of the original thread that it is perfectly homogeneous, and not, as in some cases, appearing as an accretion outside of the thread or fibre itself. The properties of

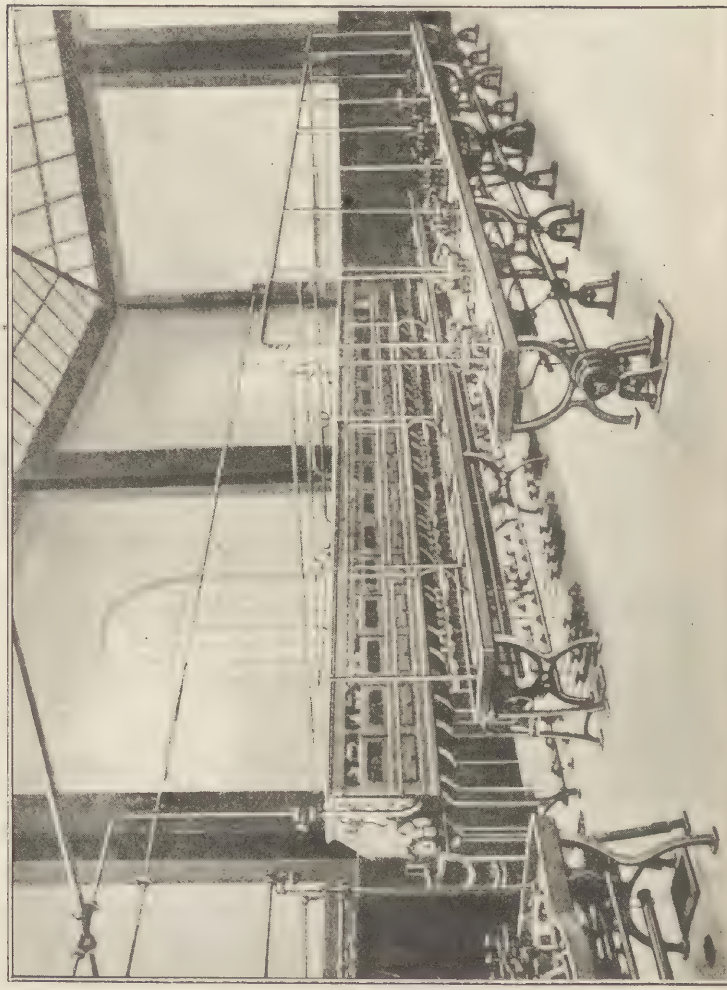
elasticity and tenacity are also important factors, specially for weaving in the single thread without twist, as also those combinations where a strain is put upon the warp threads to produce certain effects.

Careful assays are made in what is known as conditioning houses to ensure to the buyer an article specially suited to his purpose. The absorbent quality admits of too great a percentage of moisture or water being incorporated with it when sold, in fact, up to 5 or 6 per cent. over the normal, without in any way appearing fraudulent. To arrive at a fair condition 500 or 600 grammes are carefully weighed, and afterwards enclosed for fifteen or twenty minutes in a specially constructed apparatus or oven, superheated up to about 300° Fahr. It is then weighed and 11 per cent. added to the absolute dry weight, by which percentage it is supposed that we arrive at the proper normal condition. A further test is added by decreusage or boiling off the gum in order to ascertain that no undue weighting of fatty or other matter has been added to increase the weight of silk beyond its original condition in the raw state. The tavelle, or winding test, is only applied in the case of raw silk as a guide to the silk throwster. Five hanks are placed on the winding swifts and run for two hours at the rate of 50 metres per minute on the take-up bobbin. The number of breakages during the time are carefully tabulated, and the resultant divided into 800 gives the number of spindles one worker can superintend. Tests for elasticity and tenacity are conducted on a special apparatus called the serimetre. The normal amount of elasticity indicating a silk of good quality should not be less than 25 per cent. of its length. Tenacity or amount of strain before breakage is considered

to be satisfactory if the weight borne in grammes is four times the denier or size of the thread. For example, a 10-12 denier raw silk should bear a strain of 40-50 grammes in weight (equivalent to about 1 oz. avoirdupois), and so on in proportion with all other sizes.

Assays for size or count are made by reeling 20 skeins of a given length, weighing each separately, which will indicate the range or variation, and thus showing the comparative evenness of the thread, or otherwise, and by striking a mean average of the totals the size or count will be ascertained, by which calculations may be built up for the manufacturer. An international metric count has been established in all silk centres as approved by the Paris Convention of 1900. This is based upon the metre for length, and the gramme for the weight—*e.g.*, No. 100, means that 100 metres will weigh one gramme. What is known as the legal count for raw and thrown silks is based upon the number of half decigrammes per 450 metres, and corresponds very nearly to the former method of weighing by the denier ($33\frac{1}{3}$ deniers $= 1$ dram avoirdupois) per 476 metres. The nomenclature for counts and sizes for various textiles is so varied that the student or manufacturer should furnish himself with the small handbook of "International Yarn Tables," compiled and arranged by McLennan, Blair & Co., of Glasgow, an absolutely indispensable office guide.

The question of quality of the silks of various countries is equally varied, according to climate, soil, rearing, reeling, etc., and can only be assessed either by actual practice or a long experience in their manipulation. A few details respecting them may not be uninteresting.



French and Italian.—These are mostly yellow gum silk, in fact the yellow breeds of cocoons are indigenous, and the eggs of the white races of the far East after a few years' breeding revert to the yellow silks peculiar to these countries. Great care is exercised in the reeling to produce a well-formed and even thread. They are usually reeled in sizes of 9-11 to 12-14 deniers, according to the number of cocoons combined in one thread, and are adapted for either organzine (warp) or tram (weft) for the production of broad goods, for which they are admirably suited. The loss in boiling is 25 per cent., and great care is required in discharging the gum so as to prevent the appearance of duvet or silk-louse, to which they are somewhat liable. Some of these silks are reeled from 20 to 30 deniers in size for weaving in the gum with the single thread, and specially for the production of the network in silk lace. The productions of Spain, Austria, and Hungary may be classed with those of France and Italy.

Syrian, Brutian, Bulgarian, and Persian Silks are also carefully reeled, and in similar sizes to those before named. They are, however, of a softer nature, and not so well fitted for organzines as for tram silks. The coarser sizes of Brutian silks are largely used for weaving in the gum (single thread), and the finer sizes of Brutian and Persian silks doubled two or three fold make an excellent weft when twisted heavily for the manufacture of crêpe de chine.

Kashmir Silk is comparatively a new production. In 1897 it was non-existent. The Durbar of that province is indebted to the late Sir Thomas Wardle for its initiation and development. In the year 1900 the annual production was 57,921 lbs., and by the year 1906 it had increased to

190,736 lbs., and year by year promises a like progressive increase; the silkworm eggs are distributed to 15,784 village householders, and, reckoning an average of four persons to each family, it will be seen that some 60,000 to 70,000 persons, young and old, are engaged in this industry, which has proved very remunerative to all concerned. Factories have been established for the reeling, in addition to which some 200 hand-looms have been sent out from this country for the weaving of fabrics. The seed is imported annually from Europe, the race is univoltine, viz., one crop per annum, and the silk is therefore much superior to the ordinary silks of India from the eastern provinces. It is mostly reeled in 10-12 denier size, and finds a ready market in Lyons for throwing into weft silks, for which it is specially adapted.

Bengal Silks for export are somewhat limited. Although there are three crops or bunds per annum, the supply does not exceed 4,000 to 5,000 bales per annum. The filatures are in the hands of about four or five (European) companies, who give their productions names according to the districts from which the cocoons are obtained. Those known as Surdah, Rangamatty, Gonatea, Banjetty, Cossimbuzar, and Rose filature are among the best, and from these second and third selections are made under different titles too numerous to include in these notes. Some of the native reels are worthy of inclusion as silks of good quality, but the great bulk are of an inferior order and used by the native manufacturers for the fabric known as Pongees. The silks of the Bengal province being multivoltine, the bave is finer, and the cocoon only yields two-thirds the length of the univoltine species. The thread is

softer and more liable to duvet, but yields a bright thread after dyeing, and is especially suited for weft, particularly when dyed black. The sizes run from 10-14 to 16-20 deniers.

Cantons.—These also are the produce of multivoltines. The Cantonese produce six crops annually. The silk is similar in quality to the Bengals, but as the colour is a creamy white it lends itself to the lighter shades of colouring, and when well reeled is adapted particularly for crêpe de chine weft. Formerly this silk was all in the hands of native reelers, and very coarse and uneven. European enterprise and capital has established numberless filatures, and both for size and winding properties they compete favourably with the filature silks of other countries. There are still some native-reeled silks, but even these are of much better type than the exportations of, say, fifteen to twenty years ago. The worst fault of these native reels is that of *mariages* or double threads.

Japans have vastly improved during the last ten years, both for colour, reeling, and general characteristics. They are good winding, fairly even, firm in the thread, and capable of being dyed and weighted (especially in colours) to double their original weight when boiled off. The sizes run from 9-10 to 13-15 deniers in the single thread, so that they can be utilized for fine organzine and tram silks. The American manufacturers use these silks more extensively than those of any other province or country. One special characteristic of Japan silks is the minimum percentage of gum. The loss in boiling does not exceed 18 to 20 per cent., as against European silks and those of India and Canton 25 per cent.

Tussah Silks are the produce of the family of *Saturnides*.

In India the Antherea Mylitta produces a bave of at least 8 deniers in size, and in China the Antherea Pernyi produces a bave of about 5 deniers, as against the bave of the Bombyx Mori silks of 2 to 2½ deniers. Consequently, the original thread is flatter and more uneven, and a less number of cocoons can be combined to produce a given size. The quality is very varied. Some of the filature-reeled silks of northern China (Chefoo district) are fairly workable, but unfortunately they vary from year to year, and many chops or trade-marks in favour a few years ago are now little better than those of the native reelers. The filatures usually run 35-40 deniers in size, and those of the natives 50-60 deniers. A large proportion of the silk in China in the province of Shantung is reserved for the native manufacture of fabrics bearing that name.

China Silks cover so wide an area, and are so varied in qualities and sizes, that only a few general details can be included here, so we must confine our remarks to a general classification. (1) Filature silks produced in factories in the neighbourhood or within a fifty-mile radius of Shanghai are reeled under European supervision and take a first place in the world's productions. They are white in colour, even in size, of a firm texture, and possess great tensile strength, so that for some purposes they are preferred to any other silks, and consequently command a high price. 10,000 to 15,000 bales are now annually produced and exported, principally for Europe and America.

(2) *Re Reels.*—These silks are very similar to the native-reeled silks both as to size and quality. In fact, they are the native-reeled silks, wound by Chinese women, carefully cleared of some of the bouchons or foul by passing

through the fingers, and by re-reeling a better winding is obtained. The finer portions of the silk are selected for this purpose, so that part of the cost of manipulation in silk-throwing is saved, a great *desideratum* where the cost of manual labour is comparatively at a premium. During the last 10 to 15 years the export of these silks has been on the increase. During the season 1906-1907 they reached nearly 13,000 bales, nearly equal in quantity to those of the ordinary white native-reeled silks.

(3) *Native Reels.*—These include Tsatlees, Kahings, Hainins, Hangchows in the white silks, and the yellow silks of the Seychuen districts. Owing to the selection of the best and finest hanks for re-reeling purposes the white silks of China have greatly deteriorated. Naturally, the cocoon of the white China species is second to none; in fact, if it could be produced under the same scientific conditions as those of Europe and Japan, for strength, lustre, etc., it would be the very best. In the districts where the rearing takes place there is no microscopic selection of healthy graine or eggs, and consequently liable to the ravages of diseases to which the silkworm is subject. It is to be hoped that Western education and contact with their near neighbours the Japanese will so leaven the commercial spirit of this country that ultimate improvement may be the result. The yellow silks especially are of little utility for the English or Continental markets beyond that of coarse fabrics, or heavy sewings, or embroidery threads.

So far we have only dealt with the silk in the net or raw state, and its manipulation in the processes of reeling and throwing, but in these stages it is estimated that an equal

quantity of waste is produced, and which is now utilized for silk spinning. In the rearing of the cocoons the blaze or fine silken fibres thrown off by the silkworm on the bush as a nest on which to form its cocoon is collected, and China alone has exported 240,000 lbs. annually of this product. Imperfect and pierced cocoons which cannot be used for reeling form another source of supply. In the reeling process, before a perfect thread can be obtained for continuous running the outside threads are brushed off by an automatic process, and at least 25 to 30 per cent. of the total weight of the cocoon goes into the waste basket. To this may be added the waste made by the silk throwster in the processes of winding, cleaning, and doubling. Doubtless some portions of these waste materials were used by the ancients for all time, but under earlier conditions were combed and spun by hand. In the regulations of the thirteenth and fourteenth centuries in France mention is made of galette flourin and filoselle, productions of hand spinning, and in 1815 a society was formed in Paris for the encouragement of the industry on a larger scale and by mechanical means. At this period the waste was cut into short lengths and spun on lines similar to those then existent in the cotton spinning, but in 1830 special machinery was introduced for dealing with longer fibres, on the basis of the present system of the silk-spinning industry of to-day. To a paper read by Joseph Boden, Esq., silk merchant, of Manchester, before the Silk Association in February, 1905, we are indebted for information as to the rise and progress of this branch of textile industry in our own country. It appears that the first spinning mill established in England was in the year 1792, at Galgate, near Lancaster, but a

quarter of a century elapsed before this example was followed to any extent by other firms.

On the Continent operations were commenced in Bâle about the year 1822, and from that period both at home and abroad it has made considerable progress and development. It may be interesting to know that an approximate estimate of the spun-silk spindles in the whole world may be put at about 660,000, spread over France, Switzerland, Italy, Germany, Austria, England, America, China, Japan, and India. The production may be taken roughly at 15,500,000 lbs. per annum, of which about 11,000,000 are produced on the Continent, 3,000,000 in England, and the remainder in other countries.

The predominance gained by the Continent may be partly accounted for by the cheaper labour employed, and an abundant water supply, so necessary for the purpose of schapping, and also more favourable treatment by the absence of restrictive factory regulations. By the method of schapping, in which a portion of the gum is retained, the processes are somewhat cheapened, a larger yield is obtained, and for some purposes, specially where required for black dyeing, the yarn has a wider scope of utility for the manufacturer. The gum is partially removed by the process of maceration and fermentation or by chemical means. The English spinners succeed in spinning brighter and whiter yarns which, although higher in price, command a sale for purposes for which the Continental yarns are less suited, specially where brilliancy and clearness of colouring is desired for delicate tintings and for whites. The methods employed for schapping, for long spinning, and for what is known as short-

spuns involve different treatment and special machinery, the details of which are so varied that a special chapter would be necessary to describe them even in the most general outline. My purpose has been to show the evolution of the silk industry from the smallest and crudest beginnings up to its present conditions of expansion and improvement.

By permission of Messrs. Sulzer, Rudolph & Co., of Zurich, silk merchants, we append a complete classification of the Chinese white silks and those of Tussah filatures; also a classification of Tussah native reels by Messrs. Puthod.

CLASSIFICATIONS.

Steam Filatures.

Marks Classic.	Best Chops.
Ewo	best 1, 2
Sinchong: Factory	Extra 1, 2
Soylun: Anchor	Extra 1, 2, 3
Jinchong: Crown	Extra 1, 2
	Good Chops.
Lunwha: Double Dragon	1, 2, 3
Denegri: Rose	Extra 1, 2
Chuezen: Diamond	Extra 1, 2
Jeaykhong: Sans Pareil	1, 2, 3
Yang: Rayon d'or	1, 2, 3

Steam Filatures—*continued.*

Good Marks A.

Soyzun: Eagle	Extra 1. 2. 3
Yahwo: Soleil	Extra 1. 2
Chuntsiang: Flying Lizards	1. 2. 3
Yungtai: Double Gold Deer	1. 2. 3
Yatchong: Gold Watch	Extra 1. 2
Yahlung: Trois Etoiles	1. 2. 3
Dahlun: Stork	1. 2. 3
Yuezung: Gold Elephant	1. 2. 3
Yuenlung: Dragon	1. 2. 3
Keechong: Flag	1. 2. 3
Yuenchong: Star and Dragon	1. 2. 3
Hunkee: Tiger	1. 2. 3
Dong Yah Dzang	Extra 1. 2
Shingtze: Lion	1. 2. 3
Tsunwo: Mulberry Tree and Web	1. 2. 3
Chingwha: Worm, Leaf and Cocoons	1. 2. 3
Poa Woo: Lighthouse	1. 2. 3
Yue Lun: Tramcar	1. 2. 3
Sooking: Centaur	1. 2. 3
Lungwha: Single Dragon	1. 2. 3
Hahiho: Two Gods	1. 2. 3
Sung Mu: Médaille	1. 2. 3
Tschenglung: Flying Tiger	Extra 1. 2
Nee Chong: Bell	Extra 1. 2
Kinglung: Excelsior	1. 2. 3
Soylum: Gold Star	1. 2. 3

Good Marks B.

Yungtah: Gold Globe	1. 2. 3
Yue Chong: Snow Hill and Pagoda	1. 2. 3
Lun Chong: Flying Horse	Extra 1. 2
Jeaykhong: Black Lion	1. 2. 3
Soyzun: Cock	1. 2. 3
Sooking: Woman and Loom	1. 2. 3
Darkin: Double Phœnix	1. 2. 3
Zunchong: Double Cocks	Extra 1. 2
Whafong: Two Riding Josses	1. 2. 3
Wooshing: Sun	1. 2. 3
Tsunchong: Double Anchor	1. 2. 3
Soochow: Double Gold Pagoda	1. 2. 3
Keechong: Star and Pagoda	1. 2. 3
Yae Kih: Joss and Unicorn	1. 2. 3

Steam Filatures—*continued.*

Marks Current A.

Dong Yah Chang: Double Lions	1. 2. 3
Chiankee: Double Tiger	1. 2. 3
Jinchong: Red Star	1. 2. 3
Kinglun: Railway and Train	1. 2. 3
Young Lee: Three Sheep	1. 2. 3

Marks Current B

Chang Shing: Five Tigers	1. 2. 3
Wayuen: Steamboat	1. 2. 3
Tsuncheong: Gold Star	1. 2. 3
Sung Tai: Red Cross	1. 2. 3
Kinglun: Double Gold Horse	Extra 1. 2
Yung Tai: Moon and Rabbit	1. 2

Hupeh: Imperial Dragon	1. 2. 3
Shantung: Gold Flying Bear	1. 2. 3

Shanghai Re-reels for New York.

Best Chops.

{ Gold Dragon	Extra 1. 2
{ Gold Pagoda	1. 2. 3

Value 10/15 Taels less than Gold Dragon.

{ Dragon Flag	Extra 1. 2
{ Wild Man	Extra 1. 2
{ Stars and Stripes	1. 2. 3
{ Red Indian	1. 2. 3
{ Solstice	A. B. C.
{ Gold Globe	A. B. C.
{ Lion and Scale	1. 2. 3
{ Sheep and Flag	1. 2. 3
{ Gold Dollar	Extra 1. 2
{ Fountain	Extra 1. 2
{ Blue Dragon	Extra 1. 2
{ Flying Horse	Extra 1. 2

Shanghai Re-reels for New York—*continued.*

Value 10/15 Taels less than Gold Dragon—*continued.*

Red Almond Flower	Extra 1. 2
Green Almond Flower	Extra 1. 2
Five Lions	Extra 1. 2
Leopard	Extra 1. 2
Old Man	1. 2. 3
Two Men	1. 2. 3
Ironclad	Extra 1. 2
Torpedo Boat	1. 2. 3
Gold Double Eagle	Extra 1. 2
Silver Double Eagle	Extra 1. 2
Gold Motor Car	Extra 1. 2
Silver Motor Car	Extra 1. 2
Gold Peacock	Extra 1. 2
Silver Peacock	Extra 1. 2
Gold H (Mark)	1. 2. 3
Silver H (Mark)	1. 2. 3
Cloud Lion	1. 2. 3
Flying Stork	1. 2. 3
Gold Flying Dragon	Extra 1. 2
Silver Flying Dragon	Extra 1. 2
Gold Flying Kite	Extra 1. 2
Silver Flying Kite	Extra 1. 2
Shield and Flags	Extra 1. 2
Arrows and Bow	Extra 1. 2
Three Gold Josses	Extra 1. 2
Three Silver Josses	Extra 1. 2

15/20 Taels less than Gold Dragon.

Galley	1. 2. 3
Dragon Boat	1. 2. 3
Cloud and Dragon	Extra 1. 2
Flying Eagle	1. 2. 3
Horse	1. 2. 3
Gold Zebra	Extra 1. 2
Silver Zebra	Extra 1. 2
Gold Riding Horse	1. 2. 3
Silver Riding Horse	1. 2. 3
Gold Sycee and Boy	Extra 1. 2
Silver Sycee and Boy	Extra 1. 2
Gold Double Swallow	1. 2. 3
Silver Double Swallow	1. 2. 3
Gold Hand	Extra 1. 2
Silver Hand	Extra 1. 2

Shanghai Re-reels for New York—*continued.*

25/30 Taels less than Gold Dragon.

Crown	1. 2. 3
Woman and Loom	1. 2. 3
(Red Mark) Sun E Tah	A. B. C.
Gold Winding Mill	Extra 1. 2
Tiger	(gold) (silver) (black) Extra 1. 2
Gold Phœnix	1. 2. 3

110/120 Taels less than Gold Dragon.

Columbia	1. 2. 3
Black Lion	1. 2. 3
Wild Dragon	1. 2. 3
Small Buffalo	1. 2. 3
Three Gold Foxes	1. 2. 3
Woman and Loom (Tarkong)	1. 2. 3
,, ,, ,, (Yuenlee)	1. 2
Three Arrows	1. 2. 3
Gold Kangaroo	Extra 1. 2
Red Peacock	Extra 1. 2
Black Peony	1. 2. 3
Carriage	Extra 1. 2
Gold Eagle and Skein	1. 2. 3
Medal	1. 2. 3
Gold Stork	1. 2. 3
Blue Zebra	Extra 1. 2
Gold Buffalo	1. 2. 3
Three Men	1. 2. 3
Oregon	Extra 1. 2
Black Double Guns	1. 2. 3
Black Hand	Extra 1. 2
Red Double Swallow	1. 2. 3
Blue Mark (Sun E Tah)	A. B. C.
Red Elephant	1. 2. 3
Blue Stork	Extra 1. 2
Silver Double Rabbit	1. 2. 3
Gold Peony	1. 2

SHANGHAI RE-REELS FOR NEW YORK—*continued.*

120/130 Taels less than Gold Dragon.

Red Riding Horse	1. 2. 3
Bell	1. 2. 3
Double Fish	Extra 1. 2

10/15 Taels less than Columbia.

Yellow Lion	1. 2. 3
Gold Cash	1. 2
Red Stork	1. 2
Gold Tiger	Extra 1
Silver Stork	1. 2. 3
(Taels 20.—Dearer than Tsatlee Filature cross S. S. S. Mars)	
Mars S. S. S.	1. 2
Blue Riding Horse	1. 2. 3

Haining improved Re-reels.

Shield and Flags	Extra 1. 2
Arrows and Bow	Extra 1. 2
Green Flying Stork	1. 2. 3

HAINING FILATURES CROSS-REELED FOR NEW YORK.

Best Chops.

Blue Dragon	Extra 1. 2
Fighting Cock	A. B. C.
Gold Butterfly	1. 2. 3
Watermark	1. 2. 3
Balloon	Extra 1. 2

HAINING FILATURES CROSS-REELED FOR NEW YORK—*contd.*

Good Chops.

Flying Horse	Extra 1. 2
Cock and Centipede	1. 2. 3
Butterfly and Almond Flower	1. 2. 3
Blue Lion	1. 2. 3
Gold Flying Dragon	Extra 1. 2. 3

Middling Chops.

Pegasus	Extra 1. 2. 3
Buffalo	Extra A. B. C.
Black Horse	Extra 1. 2. 3
Bicycle	Extra 1. 2. 3
Grasshopper	Extra A. B. C.
Hankonshing	Extra 1. 2. 3
Mountain and Pagoda	1. 2. 3
Gold Double Rabbit	Extra 1. 2
Red Pagoda	Extra 1. 2
Gold Lion	Extra 1. 2
Fisherman	Extra 1. 2
Gold Dollar	A. B. C.

Inferior Chops.

Double Fish	Extra 1. 2
Small Buffalo	Extra 1. 2
Eagle and Skein	Extra 1. 2
Gold Mars (Chuntah)	Extra 1. 2
Mars (Sze She Shing)	Extra 1. 2
,, (Saw E Kee)	Extra 1. 2
,, (Kunchee)	Extra 1. 2
Cupid	1. 2
Green Flying Horse	1. 2
Shanghai Bund	1. 2
Double Birds	1. 2

Tsatlée Filatures Cross-reeled for New York.

Best Chops.

Blue Dragon	Extra 1. 2
Blue Monster	Extra 1. 2
Fighting Cock	A. B. C.
Gold Butterfly	1. 2. 3
Old Man	Extra 1. 2
Stork and Cloud	Extra 1. 2
Balloon	Extra 1. 2. 3

Good Quality.

Flying Horse	Extra 1. 2
Race Horse	Extra 1. 2
Cock and Centipede	1. 2. 3
Butterfly and Almond Flower . .	1. 2. 3
Double Men	1. 2. 3
Blue Lion	1. 2. 3
Gold Flying Dragon . . .	Extra 1. 2. 3
Atlas	Extra 1. 2. 3
Plough	1. 2. 3
Gold Cock	1. 2. 3
Gold Butterfly (Cat and Bee) . .	Extra 1. 2. 3

Medium Quality.

Pegasus	Extra 1. 2. 3
Buffalo	Extra A. B. C.
Black Horse	Extra 1. 2. 3
Red Pagoda	Extra 1. 2. 3
Bicycle	Extra 1. 2. 3
Grasshopper	Extra A. B. C.
Cloud and Bridge	Extra 1. 2. 3
Blue Phœnix (Sun E Tah) . .	Extra 1. 2
Blue Mark (Sun E Tah) . . .	A. B. C.
Red Eagle	Extra 1. 2. 3

TSATLÉE FILATURES CROSS-REELED FOR NEW YORK—*contd.*

Value 5/10 Tales less than Pegasus Extra.

Green Pine and Stork	Extra 1. 2. 3
Gold Goat	Extra 1. 2. 3
Double Cock	Extra A. B. C.
Monkey and Bee	Extra 1. 2
Zee May Zee	1. 2. 3
Gold Lion (Yao-ta-zung)	Extra 1. 2. 3

15/20 less than Pegasus Extra.

Worm and Leaf	1. 2. 3
White Horse	Extra 1. 2. 3
Sun and Cloud	Extra 1. 2
Gold Double Rabbit	Extra 1. 2

Quality Inferior.

Double Fish	Extra 1. 2
Gold Dragon	1. 2
Gold Buffalo	Extra 1. 2
Small Buffalo	Extra 1. 2
Black Tiger	Extra 1. 2
Eagle and Skein	Extra 1. 2
Gold Mars (Chuntah)	Extra 1. 2
Gold Mars (Pee Va May)	1. 2
Gold Dollar	A. B. C.
Oregon	Extra 1. 2
Gold Unicorn	Extra 1. 2
Black Unicorn	Extra 1. 2
Mars S. S. S.	Extra 1. 2
Mars Tokong	Extra 1. 2
Mars S. Y. K.	Extra 1. 2
Double Birds	1. 2
Mercury	Extra 1. 2
Tower	A. B. C.
Fan	1. 2. 3
Gold Pony	Extra 1. 2
Gold Clock	1. 2
Gold Lion (Taikee)	1. 2
Blue Phœnix (Yao-ta-zung)	1. 2
Mars (Kungkee)	1. 2
Steamboat	Extra 1. 2

Tsatlée Filatures Cross-reeled for New York—*contd.*

Quality Inferior—*continued.*

Genet	1. 2
Blue Eagle	1. 2
Flag Keechong	1. 2
Locomotive	1. 2

Tsatlées Filatures (Ordinary).

Best Chop.

Crown	1. 2. 3
Good Quality.	
Buffalo	A. B. C. D.
Pegasus	1. 2. 3. 4
Black Horse	1. 2. 3. 4
Red Eagle	1. 2. 3. 4
Mountain and Pagoda . . .	1. 2. 3. 4
Blue Pheasant	1. 2. 3
Grasshopper	A. B. C. D.
Red Dragon	1. 2. 3. 4
Red Pagoda	1. 2. 3. 4
Bicycle	Extra 1. 2. 3. 4
Blue Lion	1. 2. 3. 4
Black Lion	A. B. C. D.
Medium Quality.	
Gold Flying Eagle	1. 2. 3. 4
Gold Stork	1. 2. 3. 4
Gold Goat	1. 2. 3. 4
Blue Goat	1. 2. 3
Double Cock	A. B. C. D.
Green Pine and Stork . . .	1. 2. 3. 4
Black Eagle	1. 2. 3
White Horse	1. 2. 3
Gold Mandarin Duck . . .	1. 2. 3. 4
Yellow Tiger	1. 2. 3. 4
Triton	A. B. C.
Fan	1. 2. 3
Gold Eagle	1. 2. 3

Tsatlées Filatures (Ordinary)—*continued.*

Inferior Quality.

Small Buffalo	1. 2
Double Fish	Extra 1. 2. 3
S. S. S. Mars	1. 2
S. E. K. Mars	1. 2
Gold Dollar	A. B.
Cupid	1. 2
Black Unicorn	1
Evergreen	1. 2
Blue Phœnix (Yao ta Zung)	1. 2
Gold Phœnix	1. 2. 3
Shanghai Bund	1. 2
Pee Va May Gold Mars	1. 2
Chuntah Gold Mars	1. 2
Mercury	1. 2
Eagle and Skeins	Extra 1. 2. 3
Red Stork	1. 2
Gold Unicorn	1. 2
Gold Flying Tiger	1. 2. 3
Flag	1. 2. 3
Double Birds	1. 2
Kunchee Mars	1. 2
Blue Eagle	1. 2
Genet	1. 2
Steamboat	1
Gold Lion	1. 2. 3
Star and Cloud	1. 2

Haining Filatures (Ordinary).

Best Chop.

Crown	Extra 1. 2. 3

Good Quality.

Han Kon Shing	Extra 1. 2. 3. 4
Mountain and Pagoda	Extra 1. 2. 3. 4
Gold Pheasant	A. B. C. D.
Grasshopper	A. B. C. D.
Pegasus	Extra 1. 2. 3. 4

Haining Filatures (Ordinary)—*continued.*

Good Quality—*continued.*

Bicycle	1. 2. 3
Black Horse	Extra 1. 2. 3. 4
Red Dragon	1. 2. 3. 4
Gold Flying Eagle	1. 2. 3. 4
Buffalo	Extra A. B. C. D.
Red Pagoda	Extra 1. 2. 3. 4
Fisherman	Extra 1. 2. 3. 4
Kangaroo	Extra 1. 2. 3
Black Lion	1. 2. 3. 4
Red Peony	1. 2. 3
Gold Double Rabbits	1. 2. 3
Sun and Phœnix	Extra 1. 2. 3
Gold Mandarin Duck	1. 2. 3. 4
White Horse	Extra 1. 2. 3. 4

Inferior Quality.

S. S. S. Mars	1. 2
Pee Va May Gold Mars	1. 2
Evergreen	1. 2
Green Lion	1. 2
Kunchee Mars	1
Star and Cloud	1. 2

Haining Books.

	Best Chops.	Good Chops.
Extra	Mountain and Pagoda. Hankonshing. Pegasus. Grasshopper.	Sun and Phœnix. Fisherman.
1	Mountain and Pagoda. Hankonshing. Pegasus. Grasshopper. Gold Double Rabbit. Double Pagoda. Black Lion. Gold Flying Eagle.	Sun and Phœnix. Fisherman. Gold Mandarin Duck.

HAINING BOOKS—*continued.*

	Best Chops.	Good Chops.
2	Mountain and Pagoda. Hankonshing. Pegasus. Grasshopper. Gold Double Rabbit Double Pagoda. Black Lion. Gold Flying Eagle.	Sun and Phœnix. Fisherman. Gold Mandarin Duck.
3	Mountain and Pagoda. Hankonshing. Pegasus. Grasshopper. Gold Double Rabbit. Double Pagoda. Black Lion. Gold Flying Eagle.	Sun and Phœnix. Fisherman. Gold Mandarin Duck.
4	Mountain and Pagoda. Hankonshing. Pegasus. Grasshopper. Black Lion.	Fisherman. Gold Mandarin Duck.

KAHING (GREEN).

	Best Chops.	Good Chops.	Market Chops.
Extra	Fish and Man Extra.		
1	Fish and Man 1. Swan 1. Mandarin Duck M.	Woman and Loom 1. Gold Swallow 1. Gold Eagle Extra.	
2	Swan 2. Mandarin Duck M M.	Woman and Loom 2. Gold Swallow 2. Gold Eagle 1.	
3	Swan 3. Mandarin Duck M M M.	Woman and Loom 3 Gold Eagle 2.	Almond Flower 1.
4	Swan 4. Mandarin Duck M M M M.		Almond Flower 2. Gold Star 1.

Tsatlées.

No.	Best Chops.	Good Chops.	Market Chops.	Inferior Chops.
4	Black Lion $3\frac{1}{2}$.	Red Elephant.		
		Mountain 1.		
	Buffalo 2.	Red Pagoda 2.		
$4\frac{1}{2}$	Black Lion 4.	Mountain 2.		
		Bird Fongling.		
	Buffalo 3.	Red Pagoda 3.		
$4\frac{3}{4}$	Black Lion $4\frac{1}{2}$.	Blue Elephant.		
		Mountain 3.		
		Siefong.		
		Bird Chunling.		
		Buffalo 4.		
		Red Pagoda 4.		
5 Best	Mountain 4.	Yellow Elephant.		
	Gold Elephant.	Red Pagoda 5.		
5 Bonnes	Mountain 5.	Bird Yuenling.		
	Gold Lion Kintze.			
	Double Silver Elephant.	Sœyfong.		
5 Courantes	Gold Kiling.		Mandarin Duck 1.	
			Stork Foling.	
5 Ordinary	Double Blue Elephant.	Bird Seeling.	Cocoon Quanfong.	
		Jeahfong.		
		Green Elephant.	Mandarin Duck 2.	
		Blue Phœnix Lanfong.		
5 Infér.	Blue Stork Choiling.	Triple Pagoda.	Cocoon Choeyfong.	Almond Flower Siemay
	Chœy Kiling.	Bird Teayling.	Mandarin Duck 3.	Almond Flower Sielye
			Stork Cheangling.	Double Pagoda.
				Running Deer.

Kahing (White).

Extra.	1	2	3	4.
Gold Lily Flower Extra. Tsu Kee Yuen Gnaling.	Gold Lily Flower 1. Tsu Kee Yuen Kinling.	Gold Lily Flower 2. Tsu Kee Yuen Fongling.	Gold Lily Flower 3. Tsu Kee Yuen Sueling.	Gold Lily Flower 4.

Hangchow Tsatlées.

	Best Chops.	Good Chops.	Market Chops.
1 Best	Lily Flower Lantyar. Pagoda Tingfong. Peony and Phœnix Extra.	Blue Lion Extra.	Stork and Tree Extra.
1	Lily Flower Laegno. Pagoda Layfong. Peony and Phœnix 1.	Blue Lion 1.	Stork and Tree 1.
2	Lily Flower Laebing. Pagoda Deahow. Peony and Phœnix 2.	Blue Lion 2.	Stork and Tree 2.
3	Peony and Phœnix 3. Lily Flower Laeling.		

Chincums.

	Best Chops.	Good Chops.	Market Chops.
I.	Tiger Extra Best.	Peach, Tree and Nut 1 Gnoling.	Fighting Cock 1. Blue Flying Dragon 1. Double Lion 1. Gold Pagoda Extra.

Woozies.

	Best Chops.	Good Chops.	Market Chops.	Inferior Chops.
Extra	Gold Pheasant. Green Horse 1. Green Stork Extra.	Gold Butterfly.	Deer and Stork 1.	
1	Blue Pheasant. Green Horse 2. Green Stork 1.	Single Butterfly. Double Horse 1. Double Dragon 1.	Deer and Stork 2.	
2 Best	Blue Pheasant 2. Green Horse 3. Green Stork 2.	Double Butterfly 1. Double Horse 2. Double Dragon 2.	Deer and Stork 3.	
2 Market	Blue Pheasant 3. Green Horse 4. Green Stork 3.	Double Butterfly 2. Double Horse 3. Double Dragon 3.	Deer and Stork 4.	
3	Green Horse 5. Green Stork 4.	Double Dragon 4.		Gold Bear Extra. Gold Bear No. 1.

CHINCUMS—*continued.*

	Best Chops.	Good Chops.	Market Chops.
II.	Tiger Extra.	Peach, Tree and Nut 2 Gnoling.	Fighting Cock 2. Blue Flying Dragon 2. Double Lion 2. Gold Pagoda 1.
III.	Tiger No. 1.	Peach, Tree and Nut 3 Gnoling.	Fighting Cock 3. Blue Flying Dragon 3. Double Lion 3. Gold Pagoda 2.
			Gold Stork 4. Blue Flying Eagle 4.

SKEINS.

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Double Men 1. Lucky Twins 1. Three Men 1.	Double Men 2. Lucky Twins 2. Three Men 2.	Double Men 3. Lucky Twins 3. Blue Monster 1. Old Man 1. Green Monster 1.	White Stork Extra. Blue Monster 2. Old Man 2. Green Monster 2.	White Stork 1. Red Monster. Old Man 3.

SHANTUNG (FINE).

1 Best.	2 Best.	3 Best.	4 Best.
Gold Buffalo. Double Dragon 1. Lily Flower 1. Double Almond Flower 1. Black Triple Lion 1.	Gold Elephant. Double Dragon 2. Lily Flower 1½. Double Almond Flower 2. Black Triple Lion 2.	Double Dragon 3. Double Almond Flower 2½. Black Triple Lion 3.	Blue Goat. Double Dragon 4. Blue Stork.

Shantung (Coarse).

Extra.	Best.
Gold Stork Lay Vo. Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,,	Gold Stork Lert Cee. Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,,

1	2	3
Gold Stork Charpar. Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,, Gold Stork Chuntong (Tungloo). Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,,	Gold Stork Mar Deu. Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,,	Gold Stork Quay Lee. Silver ,, ,, Blue ,, ,, Gold Stag ,, Silver ,, ,, Blue ,, ,,

Yellow Silks from the Seychuen District.

Minchew	Extra	Good I.	Market I.	Best II.	No. 2 Common
Kopun	Extra	Good I.	Market I.	No. 1½	No. 2
Meeyang					
Yellow	Market I.	No. 1½	No. 2		
White	Best I.	Market I.	No. 1½	No. 2	
Fooyung					
Yellow	Best I.	Market I.			
White	Best I.	Market I.	No. 1½	No. 2	
Wongyi	Best I.	Market I.	No. 1½	No. 2	
Wangchew	Best I.	Market I.	No. 2		
Songtsan	No. 1				
Szechong	Best I.	Market I.	No. 1½	No. 2	

Tussah Filatures.

True Filatures.

Whafong: Worm and Leaf 1 and 2.
Yee Foong: Gold Double Dragon ,,
Whatai: Flag 1, Blue Cross 2.

Best.	Good A.
Spinning Girls 1.	Spinning Girls 2.
Black Pagoda 1.	Black Pagoda 2.
Sun and Pagoda 1.	Sun and Pagoda 2.
Gold Bell.	Silver Bell.
Black Monkey 1.	Black Monkey 2.
Peony 1.	Peony 2.
Gold Flying Fish.	Gold Toad.
Black Cowboy 1.	Black Cowboy 2.
Gold Unicorn 1.	Gold Unicorn 2.
White Double Elephant 1.	White Double Elephant 2.
Japanese Woman.	American and Chinese Flag 2.
American and Chinese Flag 1.	Black Double Magpie.
Black Double Magpie 1.	Wong Lie Soo.
Gold Stork.	Gold Single Man.
Black Leopard 1.	Gold Mars.
Black Pony.	Gold Woman.
Commercial Flag.	Black Single Deer.
Black Double Horses.	Black Single Goat.
	Almond Tree.
	Mandarin Horse.
	Gold Single Cock.
	Black Zebra.
	Sun.
	Gold Ostrich.
	Black Nine Ladies.
	Gold Eagle.
	Red Unicorn.
	Black Leopard No. 2.
	Double Mandarin Duck.
	Blue Butterfly.
	Gold Snake.
	Policeman.
	Black Double Lion.
	Black Flying Horse.

Tussah Filatures—*continued.*

Good B.	Good B.
Gold Single Peach.	Silver Ostrich.
Gold Double Rabbits.	Silver Eagle.
Gold Horse.	Silver Cock.
Black Firtree.	Tramway.
Black Riding Horse.	
Black Seven Stars.	Gold Double Horse.
Red Double Wild Geese.	Black Flying Dragon.
Silver Woman.	Piano Girl.

Current A.	Current B.
Pluck Mulberry.	Gold Three Men.
Gold Phœnix.	Blue Cash.
Gold Cash.	Silver Phœnix.
Gold Double Men.	Gold Double Pony.
Red Woman.	Silver Double Peach.
Black Three Elephants.	Silver Double Rabbits.
Red Cock.	Green Woman.
Red Ostrich.	Gold Mountain.
Red Eagle.	Green Locomotive.
Black Steamship.	Gold Sampan.
Red Nine Ladies.	Gold Double Birds.
Black Double Goats.	Black Double Deer.
Gold Tiger.	Black Double Wild Geese.
Blue Double Wild Geese.	Blue Eagle.
Gold Double Peach.	Blue Phœnix.
Black Double Rabbit.	Green Phœnix.
Silver Single Peach.	Bicycle.
Moon.	
Black Locomotive.	

No. 2.	No. 2 Inferior.	No. 3.
Black Fan.	Gold Lion.	Gold Dog.
Silver Mountain.		
Gold Fox.		
Three Deers.		
Red Sampan.		
Blue Sampan.		

Classification of Native Reeled Tussahs.

By Messrs. A. Puthod & Co. (Importers).

Best.	Market No. 1.	Market No. 1½.	Market No. 2.	No. 3 and Inferior.
Gold Dragon "Extra." (Ching Cheong)				
Gold Star "Extra."	Gold Star.	Silver Star.	Red Star.	Golden Vase.
Greyhound I.	Greyhound II.	Greyhound III.	Greyhound IV.	
Gold Anchor "Extra."	Gold Anchor.	Silver Anchor.	Red Anchor.	
Gold Bird "Extra."	Gold Bird.	Silver Bird.	Red Bird.	Black Bird.
Gold Cock and Flag, Best I.	Cock and Flag Gold I.	Cock and Flag Gold II.	Cock and Flag Gold III.	Cock and Flag Gold IV.
Blue Horse "Extra."	Blue Horse.	Red Horse.	Green Horse.	Yellow Horse.
Gold Lyre.	Gold Teapot.	Silver Teapot.	Red Teapot.	Gold Cat and Tree. Blue Cat and Tree.
Gold Parrot.	Gold Eagle.	Gold Pelican.	Gold Fish.	Silver Fish. Red Fish.
Blue Mountain.	Gold Mountain.	SilverMountain.	Red Mountain.	Green Mountain.
	Gold Railway.	Silver Railway.	Red Railway.	Black Railway.
	Gold Basilisk.	Silver Basilisk.	Red Basilisk.	Blue Basilisk.
Gold Cross.	Silver Cross.	Blue Cross.	White Cross.	Red Cross.
Moon "Extra."	Moon I.	Moon II.	Moon III.	Moon IV.
Gold Pheasant.	Gold Fairy and Deer.	Silver Fairy and Deer.	Red Fairy and Deer.	Blue Fairy and Deer. Yellow Fairy and Deer.
Yellow Ticket.	White Ticket.	Blue Ticket.	Red Ticket.	Ticket No. III.
	Gold Boudha.	Silver Boudha.	Red Boudha.	
Gold Temple "Extra."	Gold Temple.	Silver Temple.	Red Temple.	Black Temple. No. 3 Temple.
Gold Mandarin Extra Best.	Gold Mandarin Extra.	Gold Mandarin I.	Gold Mandarin II.	Gold Mandarin III.
	Gold Swallow.	Silver Swallow.	Red Swallow.	Blue Swallow. Yellow Swallow.
Gold Elephant "Extra." (Ching Cheong)	Gold Elephant.	Silver Elephant.	Red Elephant.	
Gold Phoenix "Extra."	Gold Phoenix I.	Gold Phoenix II.	Gold Phoenix III.	Gold Phoenix IV.
Double Magpie Gold "Extra."	Double Gold Magpie I.	Double Gold Magpie II.		
Gold Peacock "Extra."	Gold Peacock I.	Gold Peacock II.	Gold Peacock III.	

CHAPTER XVI

THE COTTON INDUSTRY

(BY WILLIAM H. COOK, OF MANCHESTER)

THE cotton branch of the textile industry has increased at such a rate during the last century in all parts of the world, and has now arrived at such proportions, that it may safely be said to occupy the foremost position among the industrial arts.

It has more money invested in buildings, plant, and stock, and employs more workpeople, directly and indirectly, than any other manufacturing branch of trade in this, or probably any other country.

It is supposed that the manufacture of cotton originated in India about 1100 B.C., and the methods then used have practically remained the same, until within a comparatively recent date. The Hindoos spun yarn and manufactured material of as fine a quality as can be produced to-day in any Lancashire mill, equipped with the best and most modern machinery. In the course of ordinary events the trade in cotton and cotton goods spread westwards, until we find it in Italy in the fourteenth, Germany, Prussia, and England in the sixteenth, France in the seventeenth, and in Russia in the eighteenth century.

The first reported importation of cotton into England

was in the year 1298, and it was mainly used for candle-wick. Manchester goods, which were principally made from a mixture of woollen and cotton, or linen and cotton, were first heard of in the year 1352.

The weight and value of the cotton used has reached an enormous amount, as will be seen from Table I., which has been compiled by the Cotton Spinners' Federation.

TABLE I.

COUNTRY.	Number of Spindles.	Cotton Used. All Kinds.
		Bales.
Great Britain	43,154,713	3,462,823
Germany	9,191,940	1,661,180
France	6,603,105	923,423
Austria	3,584,434	705,007
Italy	2,867,862	731,357
Switzerland	1,413,896	89,360
Belgium	1,110,600	190,756
Japan	1,356,713	1,068,000
Spain	1,387,500	255,754
Portugal	388,000	86,936
Russia	2,361,513	548,892
Holland	395,678	73,870
Sweden	326,860	76,559
Norway	65,776	10,647
Denmark	48,104	20,143
Levant	23,184	13,100
Egypt	39,200	4,386
United States of America	26,242,000	4,987,000
Total	100,561,078	14,909,193

These returns do not include China and some other small producing countries.

It will be noticed that the consumption per spindle varies very considerably in the different countries; this, in most cases, arises from the difference in the counts spun.

It will be seen also that 43 per cent. of the total spindles are in the United Kingdom.

The greater part of the cotton used is American, as out of the total of 14,909,193 bales used, 11,668,575 bales are of this variety.

The total production of American during the last season was 6,500,000,000 lbs. It is interesting to know that a little over a century ago an American ship which imported eight bags of cotton into Liverpool was seized on the grounds that so much cotton could not be produced in the United States.

The total world's production during the last twelve months is estimated at 8,000,000,000 lbs.

Particulars as to the number of looms and the amount of cloth produced in the various countries are not easy to obtain, but Table II. gives the fullest information obtainable in regard to the increases in production and reductions in wage costs of both cloth and yarn in the United Kingdom in the years 1856, 1880, and 1905.

Table II. is very interesting, as it shows that during the last half-century the weight of yarn produced has increased by 886·7 million lbs.

The hours worked have decreased by 7·5 per cent., and the labour cost per lb. of yarn has decreased by 55·8 per cent.

The production of cloth has increased by 7,950 million yards; the hours worked have decreased by 7·5 per cent., and the labour cost per yard has decreased by 24·36 per cent.

During the time these changes have been taking place the average wages of the operatives have increased by 94 per cent., as shown in Table III.

Table II.

Production and Costs of Cotton Yarns and Cloths in the United Kingdom.

	1856.	1880.	1905.
Raw Cotton Imports, millions of lbs.	1,023·8	1,629·2	2,203·5
Raw Cotton Exports, millions of lbs.	146·6	224·6	283·1
[1] Yarn Production, millions of lbs., average counts	745·6	1,194·0	1,632·3
Yarn Exported, millions of lbs.	182·0	215·7	205·0
Yarn for Home Consumption, millions of lbs., average counts	563·6	978·3	1,427·3
Cloth Production, millions of yards, average width	3,600·0	7,737·0	11,550·0
Cloth Exported, millions of yards	2,036·5	4,496·3	6,198·2
Number of Spindles	28,000,000	42,000,000	50,000,000
,, Looms	300,000	550,000	700,000
,, Operatives in weaving mills	175,000	246,000	306,000 [2]
,, Operatives in spinning mills	205,000	240,000	211,000 [2]
Working Hours per Week	60	56½	55½
Average Weekly Wages, 17 classes of operatives	14*s.* 6*d.*	19*s.* 10*d.*	26*s.* 2*d.*
Operatives per 1,000 Spindles	7·3	5·7	4·2
Production of Yarn per operative per year, lbs.	3,637·0	4,975·0	7,736·0
Production of Cloth per Operative, yards	20,580	31,860	37,740
Production of Yarn per Spindle per Year, lbs., average counts	27·0	28·5	32·6
Production of Cloth per Loom per Year, yards, average width	12,000	14,250	16,500
Labour Cost per lb. of Yarn, average counts	2·4*d.*	2·0*d.*	1·06*d.*
Labour Cost per Yard of Cloth, average width	·55*d.*	·447*d.*	·416*d.*

[1] Taking an average of 15 per cent. waste. Stocks not taken into account.
[2] From latest published Blue Books, 1903.

Table III.

Average Weekly Wages of Cotton-Mill Operatives, Manchester and Oldham Districts.

	1856. 60 hours per week.		1880. 56½ hours per week.		1905. 55½ hours per week.	
	s.	d.	s.	d.	s.	d.
Scutcher	8	0	13	8	24	6
Card-room Overlooker	28	0	38	6	50	0
Drawing-frame Tenter	9	0	15	0	19	0
Spinners' Overlooker	26	0	40	0	50	0
Mule Spinners (average of fine, medium, and coarse)	24	1	33	6	45	0
Mule Piecers (average of fine, medium, and coarse)	8	3	10	8	14	10
Throstle Spinners	9	0	14	0	16	0
Doffers	6	0	9	0	8	0
Reelers	9	0	12	0	17	0
Winders	9	0	14	2	18	0
Warpers	23	0	33	0	45	0
Beamers	22	0	24	9	22	0
Doubling Overlookers	28	0	24	0	35	0
Doublers	9	0	12	0	16	0
Gassers	9	6	13	0	20	0
Weavers (average number of looms)	11	2	15	3	24	0
Average of above seventeen classes of Operatives	14	6	19	10	26	2
Comparison, calculated for number of hours worked	100		144		194	

The altered conditions of the operatives are further seen by a comparison of the cost of living during the periods given in Tables II. and III. The particulars regarding cost of food have been obtained from the books of one of the large Manchester hospitals, no other data being to hand.

Table IV.

Comparative Conditions of Cotton Mill Operatives in the United Kingdom.

	1856.	1880.	1905.
Total number of Operatives employed in Cotton Mills	380,000	486,000	523,000[1]
Number of Half-time Operatives	10,050	51,000	21,000[1]
Age of Children admitted to work Half Time	9 years.	10 years.	12 years.
Age of Children admitted to work Full Time	13 years.	13 years.	13 years.
	s. *d.*	*s.* *d.*	*s.* *d.*
Average House Rents	3 0	5 0	6 0
Paid by one of the Manchester Hospitals:—			
Meat, per lb.	0 7½	0 8	0 6
Flour, per doz. lbs.	2 6	2 0	1 2
Bread, per 4 lb. loaf	0 8½	0 7½	0 5½
Sugar, per lb.	0 7	0 3½	0 1¾
Tea, per lb.	4 6	2 0	1 4
Butter, per lb.	1 2	1 0	0 11

[1] From latest published Blue Books, 1903.

One very satisfactory feature in this table is the increase in the age at which children are allowed to commence work as half-timers. It is very probable that at a near date the system of half-time working will be abolished in the cotton trade, as has been done for some years in the engineering trade.

These increases in production have not arisen through any great mechanical invention, seeing that all the radical patents for spinning and weaving machinery are dated prior to 1825, with perhaps one or two exceptions, such as the Heileman Comber, the automatic feeder for openers and scutchers, or the piano feed-motion regulator.

Wyatt invented the drawing frame, and Kay the fly shuttle in 1738; Lewis Paul the card in 1748, and the clever doffing comb mechanism about 1750.

Hargreaves invented the spinning jenny in 1764, and Crompton the mule in 1779.

The scutcher was invented in 1797, to be improved by the addition of the lap-end by Mr. Creighton fifty years later, and the piano-feed regulator by Mr. Lord in 1862.

Holdsworth brought out his wonderful differential motion in 1830. It is so far back as 1825 that Richard Roberts invented his self-acting mule, and even the ring frame, which has made such tremendous strides during the last thirty years, was invented more than eighty years ago.

There has, however, been a steady improvement in the details of the various machines, and in the methods of production by the machine-makers, so that it is possible to run at much higher speeds, and for the operative to attend a much larger number of spindles than formerly.

A few of these improvements may be briefly mentioned :—

(1) The revolving flat card, in which the old rollers and clearers of the roller and clearer card, with the inconvenience and dirt, are replaced by a travelling apron of flats or combs. This machine has taken many years to secure universal adoption, but on account of the cleaner work produced and the less cost for attention it is now used in almost every case except for very low counts and waste; but it must be said that there are still many people who contend that the greater amount of waste made more than counteracts the saving in labour.

The percentage of waste in the roller and clearer card is generally about 2, whereas in the revolving flat card it is 5.

(2) Another great improvement is the presser used in connection with preparation frame spindles. This is a very simple but most effective addition to the spindle, and consists of the addition to the old flyer of a loose leg, to which is added a foot called a presser. The outer part, or leg, is heavier than the inner part, or foot, and during revolution the centrifugal force of the leg being greater than that of the foot causes an inward pressure on the bobbin, thus enabling the machine to make a bobbin which is not so liable to damage in the after-process, and also contains a much greater length of material. This improvement has tended, in a great degree, to the reduction of cost in the preparatory stages of spinning.

(3) The piano-feed regulator, patented in 1862 by Mr. Lord, is also worthy of notice. This invention has for its object the regulating of the lap. It consists of a number of pedals like the keys on a piano. These pedals "feel" the cotton, and if it is too thick or too thin they put into action a motion which decreases or increases the rate of feed, thus automatically adjusting the volume of cotton in accordance with the weight per yard decided upon.

(4) Another patent of importance is the "Rabbeth" spindle for ring spinning and doubling frames. When the ring frame was first introduced it had top and bottom bearings for the spindle, which required oiling every day. This, besides being troublesome, was liable to cause dirty yarn, and it was not possible to run the spindle at a greater speed than 5,000 revolutions per minute, whereas the "Rabbeth," or self-contained gravity spindle, only requires oiling about every two months, and even with an unbalanced bobbin will run steadily at 20,000 revolutions per minute,

a speed much higher than is required, the maximum speed at which the worker can attend to the frame being about 10,000 revolutions. It will readily be seen what a great effect this patent has had in increasing the production of yarn.

(5) Another patent is the cross-winding frame. This machine was rendered necessary mainly on account of the changes in the location of the spinning and the weaving mills, and to meet the different conditions existing between mule and ring spinning mills, as also the hostile foreign tariffs. These varied conditions made it necessary to be able to send the yarn from place to place with the smallest possible amount of tares.

(6) Then of late years we have had the introduction of the automatic feeder into the blowing-room. This machine automatically regulates the supply of cotton to the cylinder or beater of the opener, and thus more regular laps of cotton are produced than formerly, besides reducing the cost of attention 50 per cent.

(7) For certain classes and qualities the yarn spun on the mule is still considered to be superior to that produced on the ring spinning frame, especially for the very fine counts. Although the self-acting mule was invented and introduced some considerable time previous to 1856, the main principles are still the same, and the same facts hold good that this machine has only been improved in its detail parts. One of the main advances is concerning the number of spindles per mule. In 1856 and 1905 they were 500 and 1,300 respectively.

(8) Finally, there is the introduction of the various new types of looms. Previous to these there had been no radical alterations in the design of the loom for more than

fifty years. The automatic loom has made rather slow progress in England up to the present time, but there is no doubt they have come to stay. When it is borne in mind that a weaver can only attend to six looms of the old type, as a maximum, whereas he can attend to twenty-four or more of the new type, it will be seen that these automatic looms have a future before them.

In 1856, the earliest period in the tables of comparison, on page 323, the average spinning mill was constructed on very unsatisfactory principles, and it would contain about 30,000 spindles.

The mills generally had narrow, low, dark and ill-ventilated rooms, and the sanitary arrangements were exceedingly poor and unsatisfactory.

The power was in some cases transmitted by means of a water wheel, but steam engines were more generally adopted. These engines were of the beam type, single condensing, with cylinders up to 60 ins. diameter, and 8 ft. stroke, running 20 to 30 revolutions per minute. The steam pressure was from 20 to 60 lbs. per square inch, and the consumption about 25 lbs. of steam, and $3\frac{1}{2}$ to 5 lbs. of coal per indicated horse-power.

The power was transmitted to the various rooms by means of spur gearing.

The spinning spindles were either of the mule or flyer type, running at 6,000 and 3,500 revolutions per minute, and producing ·52 lbs. and ·4 lbs. of yarn average counts, 32*s*. per spindle per week of 60 hours respectively.

The cost of such a mill was from 45*s*. to 50*s*. per spindle, including buildings, boilers, engines, machinery, and accessories. The cost of a weaving shed was £15 per loom.

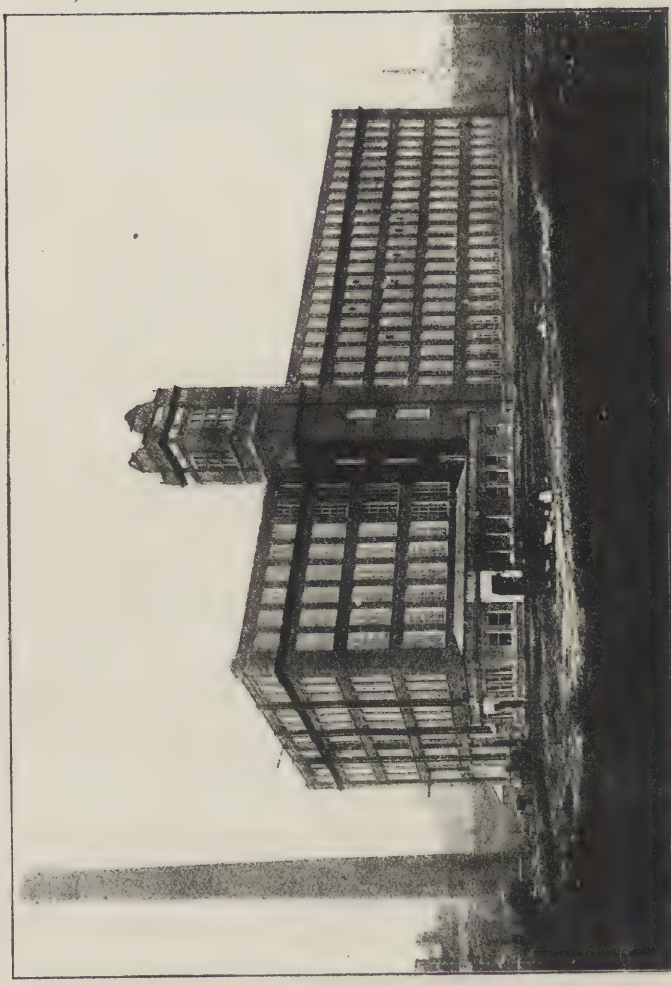


Fig. 75.—Modern Ring Spinning Mill.

At the present time the average mill contains about 80,000 spindles, and the yarn produced may be taken at an average of 40*s*. counts. The buildings are of the most approved design for cheap production and economical driving, and the sanitary arrangements are of the latest.

The machinery is so arranged that the raw cotton from the bale passes through the various machines until it arrives in the warehouse in the form of yarn, without traversing the same ground twice; that is, it pursues the shortest course possible to save cost in handling.

This is clearly shown on Fig. 75, which gives the arrangement of one of the most modern ring spinning mills, built in the shed form. This type has been adopted here because the whole of the processes in spinning and weaving can be clearly shown. In Fig. 76 a plan of a mill taking the cotton from the raw state to the finished product is given.

The power is mostly transmitted by steam engines, although great efforts are at present being made to introduce driving by electricity. Many mills in foreign countries have been arranged with this drive, particularly where there is a plentiful supply of water, which enables the engineer to install water turbo-generators, and to produce the electrical power much more cheaply than where steam is used.

Several mills have been fitted up in England recently with electrical driving, but the results have not yet been made public, so that it is not possible to say what prospects there are for this type of driving.

Steam turbines have also been installed into several mills with very satisfactory results.

Where steam engines are used they are of the recipro-

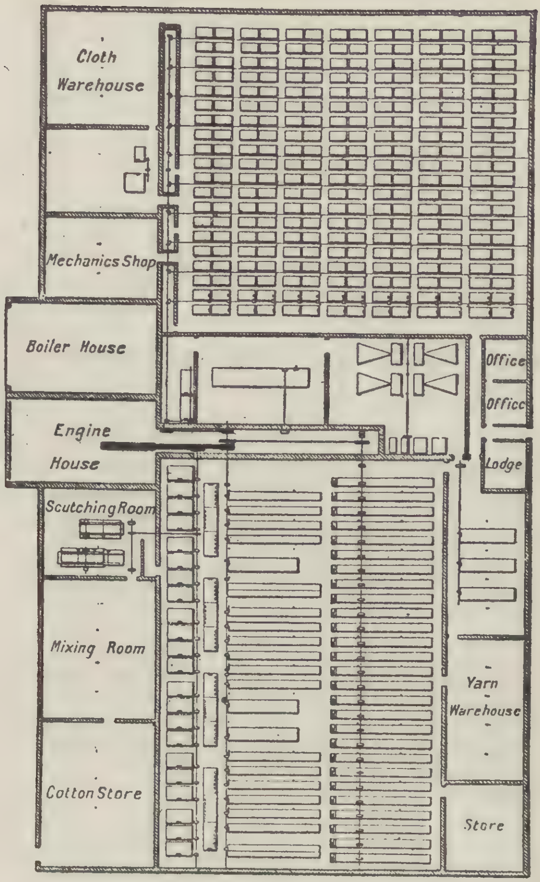


FIG. 76.—Plan of Cotton Mill.

cating type, either vertical or horizontal, with double, triple, and in some cases quadruple expansion, and of powers up to 2,500 indicated horse-power. The cylinders are made up to 66 in. diameter, with stroke up to 6 ft.

The crank shafts make 60 to 80 revolutions per minute, and are fitted with fly-wheels in the form of rope pulleys up to 30 ft. diameter, prepared to receive as many as fifty ropes of $1\frac{5}{8}$ in. diameter for driving the main shafts in the various rooms, thus dispensing with all spur gearing, giving greater freedom from breakdown, and much smoother and quieter running.

The steam consumption is from 12 to 16 lbs. of steam, and the coal consumption about $1\frac{1}{2}$ to 2 lbs. per indicated horse-power.

In cases where superheated steam is used the compound engine is about as economical as the triple expansion working under ordinary conditions.

The present mill hours are $55\frac{1}{2}$ per week.

The flyer frame has become almost obsolete, and the mills are either filled with ring or mule spindles, or in some cases both types of spinning machinery.

The speed of the spindles is—mule 11,000 revolutions, ring 9,500; and the production ·75 lbs. mule, and 1 lb. ring average counts 40*s*. per spindle per week respectively.

The various processes through which the cotton passes from the bales to the yarn or cloth are shown in the form of a diagram on page 334 (Fig. 77).

The cost of a mule mill is about 23*s*. per spindle, and the cost of a ring mill from 38*s*. to 42*s*. per spindle inclusive.

The cost of a modern weaving shed is about £26 per loom.

Most of the extra cost per spindle in the ring mill arises from the greater production per spindle, which, as a consequence, requires more preparation machinery.

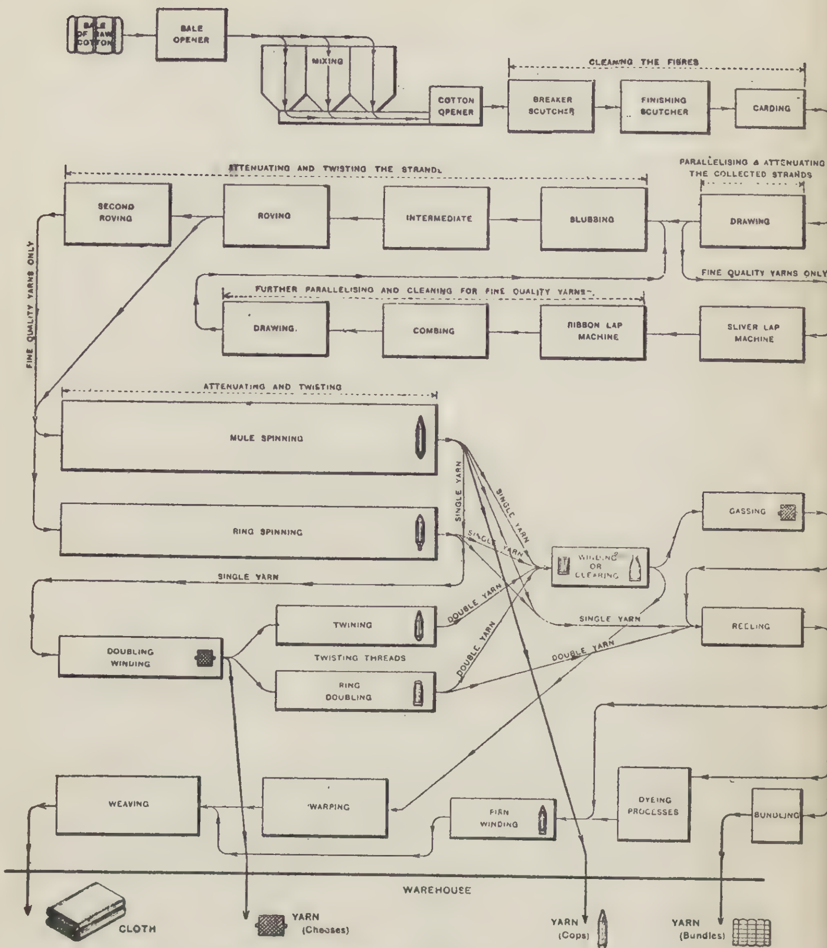


FIG. 77.—Graphic Illustration of Processes in Cotton Manufacture.

The greater cost of the modern weaving shed arises from the far superior manner in which it is fitted up.

The great reduction in the cost of erecting the modern

mill is further apparent when it is known that the average wages of the employees in the machine works have increased $12\frac{1}{2}$ per cent., and the hours have been reduced $7\frac{1}{2}$ per cent.

It has only been possible to do this by the introduction of labour-saving machinery of the highest type.

The machine construction branch of the textile industry is now so well organized that even with the heavy duties which are imposed by foreign countries the greater part of the machinery used in all parts of the world is produced in England, and there does not appear to be any reason to fear that for a long time to come England will lose her supremacy in either the machine-making or the spinning or manufacturing branch of the textile industry.

CHAPTER XVII

THE LINEN INDUSTRY HISTORICALLY AND COMMERCIALLY CONSIDERED

By Fred Bradbury, Professor of Textile Industries, Municipal Technical Institute, Belfast.

The cultivation of the flax plant, the separation of the fibres from the straw, the preparing and spinning of these same fibres into yarns, and their subsequent manufacture into linen cloth form to-day no insignificant branch of the textile industry, employing, as it does, tens of thousands of persons in the various progressive sections from the sowing of the flax seed to the distribution of the finished woven product.

Earliest Records.

The Biblical records testify that flax was cultivated, yarn spun, and linen fabrics woven in the patriarchal times. It is also interesting to know that the manufacture of *fine linens* is spoken of in all classical records, books, and writings from the earliest times.

If the growth of flax, together with all the subsequent processes of preparation and manufacture into cloth, were considered from the point of antiquity alone, it would form an interesting volume, since most people manifest an

intense interest in anything which can justly claim to have its foundation in prehistoric times.

Flax.—The first mention in the sacred writings of *flax* by that name occurs in connection with the plagues of Egypt (Ex. ix. 31): "And the *flax* and the barley were smitten, for the barley was in the ear and the flax was bolled." The virtuous woman is described by Solomon as one who "seeketh wool and *flax* and worketh it with her hands. . . . She layeth her hands to the spindle and her hands hold the distaff. . . . She maketh fine linen and selleth it" (Prov. xxxi. 13, 19, 24).

Scriptural Records: Linen.—The first scriptural record of *linen* described by that name is found in Gen. xli. 42: "And Pharaoh took off his ring from off his hand and put it upon Joseph's hand, and arrayed him in vestures of *fine linen*, and put a gold chain upon his neck." This was in 1715 B.C., when Pharaoh exalted Joseph to the second position in the kingdom. Though this is the first reference to *linen* in the Scriptures, it is very evident that linen fabrics were made long before this period, since the reference is to *fine* linen, and *fine* linen can only be manufactured after many efforts and long experience. The sackcloth which Jacob put on (Gen. xxxvii. 34), when Joseph's coat of many colours was brought to him, was in all probability made of coarse linen cloth. Some historians contend that coarse fabrics of flax were produced in the antediluvian age, and that the covering of Jabal's tents (Genesis iv. 20, 3875 B.C.) were made of some coarse flaxen or hempen material.

Linen—Emblematic of Purity.—Wherever cleanliness and purity were required the chosen symbol among fabrics

was linen, and in this respect it stands unique among all textile fabrics, and as such is spoken of as being of service in the glorious hereafter. Moses, in enumerating to the people the articles which might be offered for the fitting and completing of the tabernacle, says: "And blue and purple and scarlet and *fine linen* and goat's hair" (Ex. xxv. 4). Later, when Aaron and his sons were set apart as priests unto the people, instructions were given that Aaron's coat was to be embroidered in *fine linen*, and that his sons were to wear *linen* breeches. Further, whenever the Jewish priests entered in at the gates of the inner court of the sanctuary they were to be clothed with linen garments and no wool was to be upon them while they ministered within the gates. They were also to have linen bonnets upon their heads and linen breeches upon their loins during the ceremony, and were not to be girded with anything that causeth sweat (Ezek. xliv. 17, 18). St. John the Divine describes the seven angels as being clothed in pure white linen, and says: "For the fine linen is the righteousness of the saints;" and again: "The armies which were in heaven followed him upon white horses clothed in fine linen, white and clean."

Evolution of the Linen Manufacture.

Egypt—the Birthplace.—Historians generally agree that linen was first manufactured in Egypt. The flax plant was indigenous to the soil of Egypt, the climate and the Nile were favourable to its growth, and there appears to be no doubt as to its extensive cultivation in the earliest history of the country. It is an established fact that linen cloths were made in Egypt more than 4,000 years ago,

specimens of the linen having been discovered in the land of the Pharaohs which were proved to be at least that age. Solomon had *linen yarn* brought out of Egypt, and the king's merchants received the *linen yarn* at a price (2 Chron. i. 16).

As already intimated, many of the fabrics woven in those early times have been preserved unto the present day as a result of the practice, then common, of embalming the dead. The choice of linen for this purpose was due to the material being able to resist the development of animal life in a more marked degree than fabrics made from animal fibres, such as wool, which germinate animal life much sooner, and consequently would defeat the end they were intended to serve.

Many of the linens thus preserved were fine in texture, but "set" much closer in the warp than in the weft. This may be largely due to the method then practised of inserting the shuttle into the warp shed with the one hand and then receiving it at the opposite side by the other hand. Then, too, since there was no "lay" for beating up the weft, the operation had to be performed with the aid of a stick, which necessarily meant slow and tedious work, however skilful the weaver might be. Nevertheless, some few of the textures thus woven compare favourably with many modern productions. A specimen among these cloths in plain weave revealed as many as 90 threads per inch in the warp and 45 in the weft; a second contained 150 threads of warp with about 70 shots of weft per inch respectively, involving the use of yarns which exceeded 100 leas of 300 yards each per lb.—a fine yarn and sett! One specimen is recorded to have contained at least 250

double threads per inch, with half the number of weft threads for the same length. The ancient tombs of Egypt reveal by pictures and other hieroglyphics the progressive stages through which the flax passed in those prehistoric times, and, singularly enough, the preparation of the fibre as then practised corresponds in many respects to the present method adopted, especially in Ireland. Some consider this an indication that the origin of the industry in the Emerald Isle was due to the migration of some Egyptians skilled in the art. There are many evidences to show that the Egyptians produced more yarn than their looms could weave and more cloth than the people themselves could consume, which, combined with the fact that they were not a commercial or maritime people, gave an opportunity to the Phœnician traders, who navigated the high seas for thirteen centuries to distribute their yarns and woven products. Much of the latter was first delivered in Tyre, where the inhabitants dyed the fabrics in colours, for which they were famous, and afterwards the Phœnicians re-exported the goods to Persia, Arabia, Palestine, Greece, Italy, Spain and France, etc.

Decline of Linen Manufacture in Egypt.—Eventually, as the years rolled on and Imperial arrogancy and oppression increased with the succeeding decades, the great enterprise hitherto displayed by the Egyptians in the peaceful arts and hereditary skill in textile crafts began to wane and gradually decayed.

Carthage, Babylon, and Greece.—With the advance of time, the renowned city of Carthage conducted the maritime commerce of the world, and discharged the duties of factor in *fine linens* as well as other textile materials. These

goods they sent westward into the countries of Europe, including Britain. In Babylon and the whole region of the Euphrates the cultivation of flax was largely carried on, and the manufacture of linen was common in all the cities on the banks of the Tigris; but this industry has long since become extinct in these countries. Greece had also a small share in the growth of flax and manufacture of linen, though she was never much noted in this respect.

Italy—Rome.—It is but natural to expect that Imperial Rome, exercising a world-wide influence, should seek to introduce into her country such a peaceful and profitable art as linen manufacturing. In her earliest days of conquest and supremacy she chiefly imported linens from the East. Subsequently she gave every encouragement to the manufacture of the finest linens in several parts of Italy. The most important step probably ever taken in this respect was when she formed guilds or colleges of the factories which were noted for the manufacture of the best qualities and varieties of linens. In these Imperial factories all kinds of clothing were made for the Emperor's family and court, and also for the officers and soldiers of the army. The guilds were also useful in collecting knowledge pertaining to the weavers' craft and of disseminating it by her legions throughout the whole of the Roman Empire.

Spain.—After the withdrawal of the Roman soldiers from Spain the Moors overran the country, yet it is recorded that they manufactured linens on an extensive scale and exported large quantities.

Germany and Austria.—Ever since the dawn of the seventh century the linen trade has had a home in Germany. It

is one of its oldest branches of industry, and formerly ranked amongst its most important. In 1169 the Hanse towns of Hamburg, Lübeck, and Bremen formed a league to protect their trade and commerce, of which linen products formed the most important section. The Hanseatic League existed for several centuries, during which time it distributed the linen manufactures of Germany throughout the chief centres of Europe. In sympathy with German manufacture, Austrian linens date from an early period.

France.—There was an extensive production of linens in Gaul at the time of the Roman domination of that country, and, notwithstanding all the vicissitudes of political fortune and revolution, the people have always carried on a considerable trade in the most delicate and finest of linens and other textile fabrics. This branch of the trade received its greatest check immediately following the Revocation of the Edict of Nantes, 1685, when the persecution of the Protestants became so acute that fully 600,000 skilled artisans, chiefly persons engaged in the textile trades, were obliged to leave their native land and seek refuge on other shores. About 70,000 of these refugees found a home in Great Britain or Ireland, and just as the woollen trade of Great Britain was materially assisted by the influx of these skilled artificers, so the linen trade of Ireland received its greatest impetus by their advent.

Various European Countries.—Other European countries, notably Holland and Belgium, carried on a large and important trade in linen for an extensive period. Belgium has always paid great attention to the cultivation of flax, and as far back as the tenth century she began to be famous for the manufacture of linen goods. On a somewhat smaller

scale the flax plant was cultivated and linen cloth manufactured in other countries, notably Portugal, Denmark, Norway, Sweden, Switzerland, Turkey, and Russia.

United States of America.—The United States of America grows much flax, but its manufacture is, and always has been, comparatively small. To-day she is one of the best customers of Irish-made linens. There are signs, however, that the country is about to try the experiment of linen manufacturing. Recent reports intimate the erection of an extensive plant for same in Vermont.

Great Britain and Ireland.

No historical description of the flax industry would be complete, however brief, unless some reference were made to Ireland, where to-day, and for at least half a century, the production of flax yarns and manufacture of linens have stood out pre-eminently. Of necessity this industry in Ireland is inseparably linked to that of England and Scotland. In the traditional records of the "Four Masters" of the fifth century reference is made to "the weaves," "the flax scutching stick," "the distaff," etc.; the inference is left to the reader. The laws of the judges in Ireland, known as the ancient Brehon laws, required the farmers to learn the cultivation of flax.

The earliest authentic accounts of Irish linen manufacture date from the eleventh century, but the cloth made was only for home consumption, for the first exports occur in 1272, when it is recorded that Irish linen was used at Winchester. Generally speaking, England and Scotland acquired the art of linen manufacturing before Ireland. In 1253 Henry III. patronized English linens by ordering 1,000 ells for his

wardrobe at Westminster. In the reign of Richard II. and the year 1382 a company of linen weavers, chiefly from the Netherlands, was established in London. But the climate and soil of Ireland were better adapted to the cultivation and growth of flax than those of Great Britain, and consequently she supplied the sister island with the raw material. Later, about the middle of the seventeenth century, we learn that Ireland produced more flax and spun more yarn than she could weave, and as a consequence "The merchants of Manchester bought 'lynne yarne' from the Irish in great quantities, and after weaving it into cloth returned it to Ireland for sale."

About the year 1670 the English Government sought by every means in her power to encourage the linen industry of Ireland in its entirety. At the same time she discouraged the woollen manufacture in the interests of her own manufactures of the same material. The methods, however, by which Lord Strafford (then Lord Lieutenant of Ireland) sought to promote the desired end were not always of the nature best calculated to accomplish that for which he strove; *e.g.*, "Any farmer, weaver, or linen draper who manufactures flax fibre by any other mode than that prescribed shall be punished with the severest penalty the law can inflict." Naturally the people resisted the injunction with a stubbornness that was characteristic of the times. During the year 1685, and resulting from the agitation among English woollen manufacturers, an agreement was made between the Parliaments of England and Ireland which imposed duties upon the exportation of Irish woollens, but sought in a variety of ways to improve and increase the production of Irish linens. It was not, however,

until the seventeenth century was well advanced that the Irish linen trade attained any commercial importance. Then, owing largely to the Ulster colonists from Scotland, and later, the influx of the skilled French refugees, especially one—Louis Crommelin, a wealthy Huguenot who was induced to settle at Lisburn, near Belfast—the linen industry of Ireland made rapid progress. Crommelin, on the Revocation of the Edict of Nantes, fled first into Holland, where he became personally acquainted with William, Prince of Orange, afterwards William III. of England, by whose persuasion he was subsequently induced to settle in Ireland. Here he spared no personal expense in introducing improvements for developing the linen industry, notably in regard to the spinning wheel and the loom, and involved himself in an expenditure of £10,000. For these valuable services he received a grant of £800 per annum, but owing to the death of his Royal patron, William III., the grant ceased after the second year. In the year 1712 a Royal Commission was appointed to enquire into the Irish linen trade, and reported that "Louis Crommelin and the Huguenot colony have been largely instrumental in improving and propagating the flaxen manufactures in the north of Ireland, and the perfection to which the same is brought in that part of the country is largely owing to the skill and industry of the said Crommelin." Crommelin's name, together with that of Philip de Gerard, the inventor of the wet-spinning process, is being still further perpetuated on panels in a stained-glass window devoted to the Textile Industries Department in the new Municipal Technical Institute, Belfast.

Linen Board of Ireland.—In 1711 the English Parliament

FIG. 78.—Perspective View of a Lapping Room in the olden times showing measuring, examining, folding the cloth into lengths, tying in the clips acting by the mechanical power of the lever to press

created and endowed a Board of Trustees of linen and hempen manufacturers of Ireland to further encourage and develop the linen industry. During its existence the Board expended a sum of nearly £1,750,000 sterling from Imperial taxation for this purpose and the erection of a Linen Hall in Dublin. Upon the dissolution of the Board in 1828, Ireland had established her proud position in the world as an important linen manufacturing centre, and was fast displacing in the markets of the world the products of other linen-producing countries.

Sealing of Linens.—Among the many useful regulations imposed by the *Linen Board* was the introduction of an *Official Seal* for marking *white* linens before being exposed for sale, which resulted in a much-improved and superior-woven fabric. Guaranteeing as it did correctness of length and perfection of make, it inspired public confidence in all buyers of Irish linens. Subsequently the regulation stamp was extended to *brown* linens also with equally beneficial results. (For illustration see Fig. 78.)

Progress in Irish Linens.—By the year 1730 the trade had made such progress that in one month alone Ireland sent to the metropolis three times the length received by London from the whole of Holland; and so much did the linen trade of Ireland prosper that foreign manufacturers of linens became greatly alarmed.

In 1689, when William III. ascended the throne, the export of Irish linens amounted to £12,000; in 1701 the amount reached £14,120; the fifth decade of the same century saw the total at £365,838 12*s.* 3*d.*, so that in less than half a century the trade increased 250 per cent. If to this be added the export value of linen yarns for the same

year the total value of linen exports reached half a million sterling.

In 1742 an import duty of 2*s*. 10*d*. per web was imposed on all foreign linens, and a bounty of 1*d*. per yard, later increased to 5*d*. per yard, on all British and Irish linens exported exceeding 1*s*. per yard encouraged the production of the finer fabrics.

Checks and Progress.—The linen trade of Ireland was not, however, of uninterrupted progress, for in the year 1773 about 30,000 people emigrated to America from Ulster alone, owing largely to trade being so bad. Yet statistics record that in the year 1784 the linen exports reached nearly 25 million yards, equal in value to about £1,250,000 and twelve years later the amount was practically double in quantity and value. At this time the finest linen cambrics sold at 25 guineas a web, equal to about one guinea per yard.

Bleaching Linens.—Besides favouring the growth of flax and the spinning of same, the climate of Ireland is well adapted for the bleaching of linens. In the early days this process occupied from two to three months, for it was accomplished by natural means in the open fields. Stealing linens from bleach fields was a common practice, for which offence capital punishment was inflicted until the end of the eighteenth century. Singularly enough, when capital punishment was abolished the evil decreased by 50 per cent. Prior to 1760 buttermilk was the only acid used for bleaching, but during that decade Dr. Fergusson, of Belfast, was awarded £300 for successfully applying lime to the bleaching process. Later, sulphuric acid, potash, and chloride of lime have in their turn produced great changes in this particular branch of the trade.

Modes of Exchange and Value : Eighteenth Century.—At this juncture it may be interesting to briefly consider values and methods of exchange of the period. In the year 1776 brown linens sold at $10\frac{1}{2}d.$ to $11d.$ per yard for 8^{oo}. The weaver sold his web to a draper who usually possessed a bleach green ; the cost of bleaching was from $3s.$ to $3s.$ $2d.$ per web, or $90s.$ to £5 per thirty pieces. When fully bleached the draper sent his material to London, the Linen Hall at Dublin, or to Chester. In London seven months' credit was given, in Dublin two to three months, and cash when the fabrics were sold personally and at all the local fairs (see Fig. 79). Spinners were paid $3d.$ to $4d.$ and weavers $10d.$ to $1s.$ $4d.$ per day. The setts ranged from 8^{oo} to 24^{oo}, and the prices paid for weaving were 8^{oo}, $2\frac{1}{2}d.$; 10^{oo}, $3\frac{1}{2}d.$; 13^{oo}, $3\frac{3}{4}d.$; 16^{oo}, $9d.$; 18^{oo}, $10\frac{3}{4}d.$; and 24^{oo}, $1s.$ $7\frac{1}{2}d.$ per yard. The flax spinners were frequently engaged by the drapers at $10s.$ to $12s.$ per quarter, including board and lodging. They had to guarantee to turn off from five to eight hanks per week; usually an average spinner could spin six hanks (3,600 yards per hank) of 72's. lea, *i.e.*, $72 \times 300 = 21{,}600$ yards per lb. The value of this yarn for an 18^{oo} sett was worth approximately $8d.$ per hank, $4s.$ per lb., or $11s.$ $1d.$ per bundle. Belfast had two linen halls in which she conducted her exchanges, viz., the Brown Linen Hall in Donegall Street, originally built by Lord Donegall, and the White Linen Hall, originally built by subscription in Donegall Square, but now replaced by the magnificent City Hall.

Spinning and Weaving by Machinery.—The introduction of spinning and weaving by power, though difficult at first, gradually displaced to a considerable extent the hand method,

FIG. 79.—The Local Linen Fair at Banbridge, in county Downe, Ireland, in the olden times. The weavers are holding up their webs of linen to view; the bleachers and buyers are elevated on forms examining its quality.

and also centralised the work in mills and factories. The spinning of flax by machinery was attempted in Great Britain fully a decade previous to any similar experiment in Ireland, notwithstanding that the latter country had acquired a considerable reputation for flax spinning. At

FIG. 80.—Loading flax.
From a photograph by A. F. Barker.

first it was only possible to produce by machinery the coarser and lower dry spun numbers of yarn. The first machines for this purpose were started in Cork, and later at Ballymena and Crumlin, in county Antrim, about the year 1787. The Irish Linen Board, which at that time was still in existence, sought to encourage the enterprise

by offering 30*s.* per spindle to the owners of all mills who introduced the power method, and by the year 1816 there were 6,369 spindles at work. The hand-spinning method for the finer yarns would, in all probability, have continued to this day but for the discovery of the wet-

Fig. 81.—Retting flax: putting flax in dam.
From a photograph by A. F. Barker.

spinning process by Philip de Gerard, of France, about the year 1826. This process was subsequently and successfully applied by Marshalls of Leeds, Baxter of Dundee, Mulholland of Belfast, and Murland of Castlewellan. In the year 1828 Messrs. Murland started the enterprise, and in the year following Messrs. Mulholland, now the York

Street Flax Spinning Mills, Belfast, adopted the new process, whereby it became possible, with the use of hot water, to soften the gummy matter which holds the flax fibres together, and reduce them to their ultimate length and fineness, and so to draw and spin them into yarn of a

FIG. 82.—Retting flax: taking flax out of dam after, say, ten days. *From a photograph by A. F. Barker.*

much greater length and fineness than by the dry-spinning process. Undoubtedly the discovery and practical application of same thoroughly revolutionised the spinning, and eventually exerted an immense influence over the weaving, by causing a greater demand for power looms. Ireland now began more rapidly than ever to acquire the lead over

foreign linen-producing countries in the markets of the world; and Belfast, the centre of the Irish linen trade, not only maintained, but increased her proud position among the manufacturing centres, whilst to-day she ranks as both

FIG. 83.—Flax drying.—Stack after retting.
From a photograph by A. F. Barker.

the industrial capital of Ireland and the metropolis of the world's linen industrial centres.

Statistics do not show any considerable adoption of power looms prior to 1850, but the following abbreviated table will give some idea of the development in the spinning and weaving of linen throughout the country since the advent of machinery:—

Year.	Number of Spindles in Ireland.	Number of Power Looms.
1841	250,000	—
1850	326,000	58
1856	567,980	1,871
1866	770,814	10,804
1875	924,817	20,152
1900	843,934	32,245
1906	869,146	34,723
1907	909,999	35,386
1908	913,423	35,386
Feb., 1910	939,732	35,622

The following comparative and latest official returns of spindles and power looms engaged in the linen industry in the United Kingdom and on the Continent will no doubt be interesting :—

Country.	Number of Spindles.	Number of Power Looms.
Ireland	939,732	35,622
France	545,497	18,083
Scotland	160,085	17,185
Germany	325,000	7,557
Russia	300,000	7,312
England and Wales	49,941	4,424
Italy	[1] 77,000	3,500
Belgium	[1] 280,000	3,400
Austria-Hungary	294,000	3,357
Holland	8,000	1,200
Spain	—	1,000
Norway and Sweden	—	406
[2] Total for Europe	1,829,497	43,815
,, United Kingdom	1,120,025	56,995

[1] Flax and hemp. [2] Exclusive of the U. K.

The volume of linen *yarn* exported from the United Kingdom in 1906 reached the enormous total of

14,975,500 lbs., bearing a monetary value of £1,008,831. In the year 1840 the respective totals were 28,734,212 lbs. and £1,976,830, from which date there has been a gradual

Fig. 84.—Flax spreading.
From a photograph by A. F. Barker.

decline as far as yarn exported was concerned, but an ever-increasing demand for home productions. The average annual imports of linen yarn into the United Kingdom

during the last decade reached 26,311,329 lbs. of declared value £933,426. These yarns are chiefly of the lower numbers. The linen *goods* of all kinds exported for the year 1906 amounted in value to £5,326,744, whilst the total value of linen yarns, threads, and piece goods reached £6,341,216.

FIG. 85.—Inside an Irish Scutching Mill.
From a photograph by A. F. Barker.

These summarised Board of Trade returns, together with the large amount of linen used for home consumption, added to the fact that nearly 250,000 people in Great Britain and Ireland are exclusively engaged in the growth of flax, the preparation and spinning of long vegetable fibres

(flax, hemp, and jute), the manufacture and merchanting of linen yarns and fabrics, will afford some idea of the commercial importance to which this industry has now attained.

Linen Varieties.—The varieties of fabrics made from *flax* in respect to structure, design, quality, and finish is much

FIG. 86.—Inside an Irish Scutching Mill.
From a photograph by A. F. Barker.

greater to-day than formerly. These include plains, ducks, hollands, lawns, sheer lawns, cambrics, handkerchiefs, dress linens, and unions in an ever-increasing novelty, vestings, glass cloths, drills and diapers, huckabacks, honeycomb and Turkish towels, d'oyleys, napkins, and damasks. The world-renowned cambrics were first made at Cambrai,

in France, and the same country was famous for the initiation and manufacture of lawns, while the town of Ypres, in Belgium, became noted for the manufacture of linen known as diaper—cloth de Ypres—and "holland" received its name through having been first manufactured by the Dutch settlers in Ireland. Napkins were introduced for wiping the hands, being all the more necessary owing to the lack of knives and forks at the time. For long periods these and other standard fabrics have been and probably will continue to be made, but the time has gone when the demand runs on one particular make or type of cloth to the exclusion of every other, which necessarily involves that the manufacturer who would succeed must learn to adapt himself to modern ideas and ever-changing fashions. No linen or other manufacturer can afford to stand still; to do so would be to drop out. In conclusion, every manufacturing industry which is to obtain and maintain a position in the commercial world worthy of the name must seek to educate its workpeople by giving them a progressive course of instruction in the scientific and technical principles underlying their trade; for success now depends on scientific knowledge, research, and an intimate acquaintance with the inventions, the experiments, the successes and the failures of others; and whether our nation does or does not provide every facility in this direction, we may rest assured that textile production will continue its progressive course, and will be led by those who have made themselves capable of leading by adapted thought and knowledge, combined with enlightened energy, which directs its force to meet the vast and varied requirements of the world.

CHAPTER XVIII

RECENT DEVELOPMENTS AND THE FUTURE OF THE TEXTILE INDUSTRIES

ALTHOUGH nearly all the principles employed in textile machinery were in use, say, by 1850, still with what may be termed the refined organization of the twentieth century there have been, and apparently will always be, opportunities for the improvement in so-called "details," which details are nevertheless so important that the status of the whole industry may depend upon them.

With reference to the treatment of raw materials perhaps the most noticeable development has been in the handling and in the carrying forward of the material by conveyors from one machine or room to the next machine or room.

Within the last twenty years wool scouring with the volatile agents has become a practical fact, but, curious to relate, has only become established where it has been necessary to scour large quantities of wool in a rough-and-ready manner, noticeably in the United States.

In the preparatory processes the chief advance has been in the accuracy in workmanship put into most machines, noticeably into cotton combs and wool combs. Heilmann's comb, after being suppressed in the wool trade for fifty years, is again making its appearance, and is likely to prove a marked success for certain styles of work.

Noble's comb, which for the last forty years has been placed on the market with two inner circles, is now being made with three and four, and these additional circles, with a new pressing-in motion taking the place of the old dabbing-brush, are resulting in double the work being done. More positive machines—particularly cone drawing and roving—appear to be taking the place of the go-as-you-please machines; while in the Bradford district white yarns on the French mule-spun system are now being produced in quantity, and it seems more than probable that in the near future coloured yarns will also be similarly produced, so that Bradford designers will be able to compete in the soft-coloured French styles.

In spinning, the only marked advance made—notwithstanding the trial of many hybrid machines—appears to be in the direction of a frame to take the place of the woollen mule. Messrs. Platt Bros., of Oldham, now make a frame of this type which will apparently do the work, so that it is now simply a question of the initial expense and cost of up-keep and running. A development of which more is likely to be heard in the future, is in the direction of self-doffing motions for spinning frames. With the suppression of the "half-timer" and the scarcity of "full-timers" the difficulties of running spindles in both Yorkshire and Lancashire are daily increasing. To take the place of "doffers" several mechanisms have been patented for application to both flyer, cap, and ring frames. The only two successful inventions up to the present, however, are those of Messrs. Clough, of Keighley, and H. Arnold-Forster, of Burley-in-Wharfedale, both being applied to the flyer frame. The former is said to yield 15 per cent.

more turn-off, and so may be regarded as an advantage, irrespective of labour scarcity; while the latter, although still on trial, is giving evidence of a similar saving being effected. Of course, such frames take more following from the overlooking point of view, so that the advantages and disadvantages should be very carefully considered.[1]

In warping, sizing, dressing, etc., one or two developments are to be noted. The old upright warping mill, owing to its tendency to produce a repeating defect in certain goods, is being rapidly displaced by the Scotch or horizontal warping mill in the coating trade and by the warper's beam system for the dress-goods trade. A marked development of sizing single botany warps directly on to the loom beam is to be noted, such fine counts as 1-50's and 1-60's botany being so dressed and successfully woven. The Barber warp knotter may be specially noted as a wonderful machine. It is employed with perfect success in tying-in plain warps into gears, working at the rate of 250 knots per minute. Unfortunately, it is not sufficiently reliable for fancy coloured styles, where an odd thread wrongly tied would throw the whole pattern out.

Perhaps reference should here be made to the development in warp mercerizing in preference to hank mercerizing to ensure evenness in result. Weft yarns are thus warped, mercerized in warp form, and re-wound end by end, the superior result in evenness in subsequent dyeing amply compensating for the additional expense.

[1] Between writing and publishing the above, Cap Doffing has become an accomplished fact, Messrs. Hall and Still, of Keighley, having made a number of these frames for mills both at home and abroad. As in the case of the Flyer Doffer, there are secondary advantages of almost prime importance.

In weaving machinery two developments are taking place, the one contending against the other. In the first case, the automatic or self-shuttling or spooling loom—invented in this country, but developed in the United States—is making rapid headway in the plain cotton trade, and is being seriously tried in the stuff trade. Against this certain Yorkshire and Lancashire loom-makers (especially Mr. Robert Pickles, of Burnley) are ranging specially-built and speeded-up looms of the ordinary type. In the cotton trade, in which broken picks matters little, the automatic loom is already a success, but the extent to which it can supersede the ordinary well designed and timed loom where perfect weaving is required is still undefined. In this case, as with the automatic doffer, it is possibly already demonstrated that, irrespective of the shortage of labour, there is an advantage under certain conditions. With the labour shortage it is more than probable that automatic looms will come more and more into use, as it is claimed that a weaver and one or two tenters can keep twenty-four of these looms going on standard cotton goods. For stuffs and worsteds the looms are necessarily broader and the number to a weaver is much smaller. Broken picks are inadmissible, and until recently no feeling action to bring into play the bobbin-changing mechanism to obviate broken picks has been satisfactory, the best resulting in a waste of about 5 to 10 per cent. The Arlington mills, U.S.A., however, are now employing a split bobbin indicator, in which the weft holds the bobbin together until the last two or three layers, on reaching which the pressure from the inside opens the bobbin slightly, and this in turn brings into play the

bobbin-changing mechanism. With this mechanism the waste has been reduced to 2 per cent.

Automatic looms are usually provided with a warp-stop motion in addition to a weft-stop motion and shuttle-box swell and stop-rod mechanisms. Several types of these motions, chiefly electrical, seem satisfactory for long warps, but probably none pay for short warps, as the initial cost is considerable and the cost of resetting on a new warp not inconsiderable.

In designing and cloth construction the chief advance made has been in designing single-yarn soft-goods styles such as Amazons, nuns' veiling, etc., and in producing soft lightly-twisted mohair goods by twisting the mohair with cotton for weaving purposes, and then extracting the cotton in the finishing operation, leaving the mohair everything that can be desired as to lustre, softness, lightness, etc. Within the past ten years some remarkable endeavours have been made to simplify and accelerate designing methods, notably in the "Designograph" of Mr. Mackintosh, "Photographic Designing" of M. Szczepanik and "Electric Card-cutting" by Messrs. Szczepanik and Zerkowitz. Unfortunately, in no single instance has any lasting impression been produced on the methods in vogue for the production of textile designs. Again, so far as jacquards are concerned, the medium pitch and the Verdol, or fine pitch machines, are undoubtedly making headway, especially on the Continent. These, however, involve no change in principle. The Carver electric jacquard, however, is very different from the ordinary jacquard, and for pure reversibles may prove a success. It is being tried in Ireland at the present moment for

the production of standard linen fabrics of elaborate floral design.

So far as finishing is concerned the greatest advances have been made in finishing mercerized and soft French goods, chiefly on the initiative of the Bradford Dyers' Association. Fabrics have been built up from mercerized cotton, specially to stand and show to advantage the Schreinering process with truly remarkable results, certain black goods being almost undistinguishable from fine satin goods made of the best organzine silk. So far as the French goods are concerned, the better grades are now being woven and finished in Bradford in bulk, but in the lower grades the French manufacturers and finishers still lead.

In the design and construction of spinning, weaving, and finishing mills and sheds steady advance has been made. New mills and sheds are so designed that, as a rule, they are admirably adapted for the particular purpose in view. Two advances, however, claim more than passing comment. These are "electric driving" and "lighting." The mechanical drive is so fully understood and developed that to say the least, the electrical drive advocates have "a hard nut to crack." At the present, taking everything into account, electric driving seems to cost at least half as much again as mechanical driving; but the electrical men are so strenuously endeavouring to bring down the price of electricity that the situation, to say the least, is interesting. Of course, there are many cases where an electric drive is obviously the best drive, and even if electricity does not supersede the steam engine in large works, it will obviously be more and more employed in the small concerns which day by day are springing up. In lighting, again, electricity

is held by gas-lighting in various forms,[1] expense and deterioration of light being the difficulties. Two special electric lights are, however, making marked headway, viz., two forms of colour-correct light and the inverted arc light. The first weaving shed has just been lighted by the colour-correct light, while the value of the inverted arc light in suppressing shadows makes it specially useful in sheds and rooms sufficiently high, and in which specially high machinery is not installed. Incandescent gas-lighting has proved so successful in the past that it is not likely to recede in usefulness in the future. Gas-lighting under pressure, however, is the latest development which appears to be making headway. This section would not be complete without reference to the attempts made to control the atmosphere in our spinning and weaving sheds. Our climate is so equitable that it is still questionable whether marked advantages accrue from the adopting of humidifying, ventilating and heating systems; but in other countries less fortunately situated the extremes of heat and cold, in summer and winter respectively, must be corrected. Upon the whole, for reasons which cannot be elaborated here, it is probable that even our favourable natural condition may be controlled and modified to considerable advantage.

In all branches of the industry, from the raw materials room to the counting-house, labour-saving contrivances are continually being introduced, principally from the United States. Day by day the industry becomes more complex and more difficult to grasp. In the past men might keep their accounts in their heads and leave their million of money, but in the future very different methods must prevail. Scientific method—deliberate intent, not casual

[1] The Keith Pressure System is one of the best of these.

acquaintance and drift—will be absolutely necessary in the near future in both acquiring the knowledge of and directing a business. Unless we are prepared to admit this and live up to it we must be prepared to see our strenuous present-day friends of the East, the Japanese (and probably the Chinese), with their freshness and directness, reap the benefit of our experience, simply because we shall be unable to reap it ourselves. The great question for us at the present time is not "Do we believe in technical education?" but "Do we feel and realize the complexities of modern conditions and the consequent necessity for scientific method?" If we once feel this technical education will be accepted without question, and instituted not in a half-hearted way on necessarily inefficient lines, but rather on a generous scale to enable the rising generation to grasp the helm, not to be tossed about at the mercy of wind and tide.

THE FLAX SUPPLY.

	Irish Production.	Imports.	Exports.	Net Supply.
	Tons.			
1896	10,844	36,650	4,565	42,929
1897	6,818	37,715	4,446	40,087
1898	6,281	34,440	3,634	37,087
1899	6,743	40,145	3,438	43,450
1900	9,479	31,563	3,789	37,253
1901	12,797	28,785	3,839	37,743
1902	10,975	29,727	4,129	36,573
1903	8,064	38,168	3,487	42,745
1904	8,069	33,024	3,446	37,647
1905	10,073	40,063	2,771	47,365
1906	11,812	37,332	3,276	45,868
1907	11,571	46,201	3,845	53,927
1908	8,421	32,511	4,242	36,690
1909	7,565	42,828	4,587	45,806

World's Production of Cotton.

	Bales.	Per cent. of Total Production.
United States	10,882,385	65·9
British India	2,444,800	14·8
Egypt	1,296,000	7·8
Russia	620,000	3·8
China	428,000	2·6
Brazil	370,000	2·2
Mexico	85,000	0·5
Peru	55,000	0·3
Turkey	80,000	0·5
Persia	51,000	0·3
Other Countries	200,000	1·3

The world's commercial production of the last five years has been :—

	Bales.
1904	18,803,000
1905	15,747,000
1906	19,942,000
1907	16,512,185
1908	19,120,420

New Sources of Cotton Supply.

Estimated Cotton Production in Other Countries.

(In thousands of bales.)

Country.	1907–8.	1906–7.	1905–6.
Japan	15	35	20
Korea	70	50	70
China	1,000	800	750
Indo-China	15	15	20
Dutch East Indies	12	13	15
Philippines	6	6	6
Asiatic Russia, Turkestan	750	675	612
Persia	80	60	50

NEW SOURCES OF COTTON SUPPLY—*continued.*

ESTIMATED COTTON PRODUCTION IN OTHER COUNTRIES—*continued.*

(In thousands of bales.)

Country.	1907—8.	1906—7.	1905—6.
Asia Minor	125	85	100
Turkey	5	8	8
Cyprus	1	2	1
Greece	15	10	10
Italy	5	3	10
Africa, French	2	1	·5
,, East and Central	7	6	6
,, West	50	12	12
,, Sudan	6	19	15
Australia and New Zealand	1	—	·2
Pacific Islands	—	—	·2
Peru	110	70	90
Chili	—	1	5
Argentina	2	1	1
Colombia and Venezuela	10	5	1
British West Indies	15	11	6
Hayti	10	7	10
Mexico	90	180	250
TOTAL (estimated)	2,402	2,075	2,069

Below are the figures of the cotton crops for the countries named for the two seasons particularized:—

Country.	1907—1908.	1906—1907.
American (United States)	11,572,000	13,511,000
Brazilian	2,867,000	
Egyptian	964,622	926,636
	1907.	1906.
East Indian	4,880,000	4,435,000

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